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Yasui et al.

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(54) **COMPUTER SYSTEM AND DATA PROCESSING METHOD FOR COMPUTER SYSTEM**

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(51) **Int. Cl.**
G06F 11/00 (2006.01)

(52) **U.S. Cl.**
USPC **714/4.11**; 711/162

(58) **Field of Classification Search**
USPC 714/4.11, 6.2; 711/162
See application file for complete search history.

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(74) *Attorney, Agent, or Firm* — Mattingly & Malur, PC

(57) **ABSTRACT**

A plurality of computers to execute jobs, a management computer to manage the execution of jobs and the disposition of data in the computers and a storage device storing data are interconnected via a network. The management program for the management computer divides the data into distributed data according to hint information and distributively disposes the distributed data and their replicas in memory storages allocated in memories of the computers. The computers execute the job using the distributed data allocated to their own memory. In the event of a fault in any of the computers, the management computer requests computers having the replicas of those distributed data disposed in the faulted computer to re-execute the job.

10 Claims, 18 Drawing Sheets

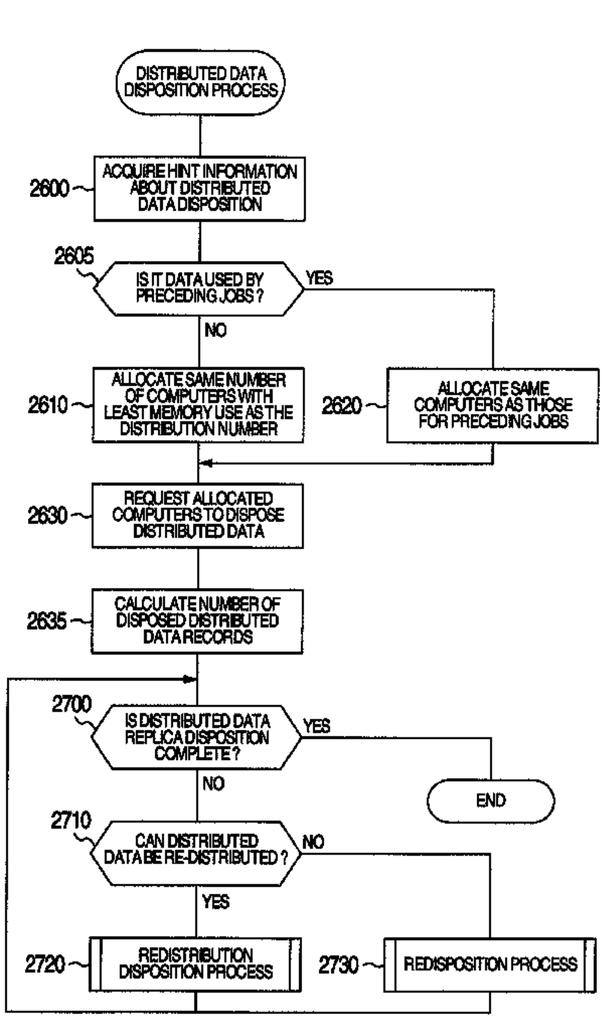


FIG.1

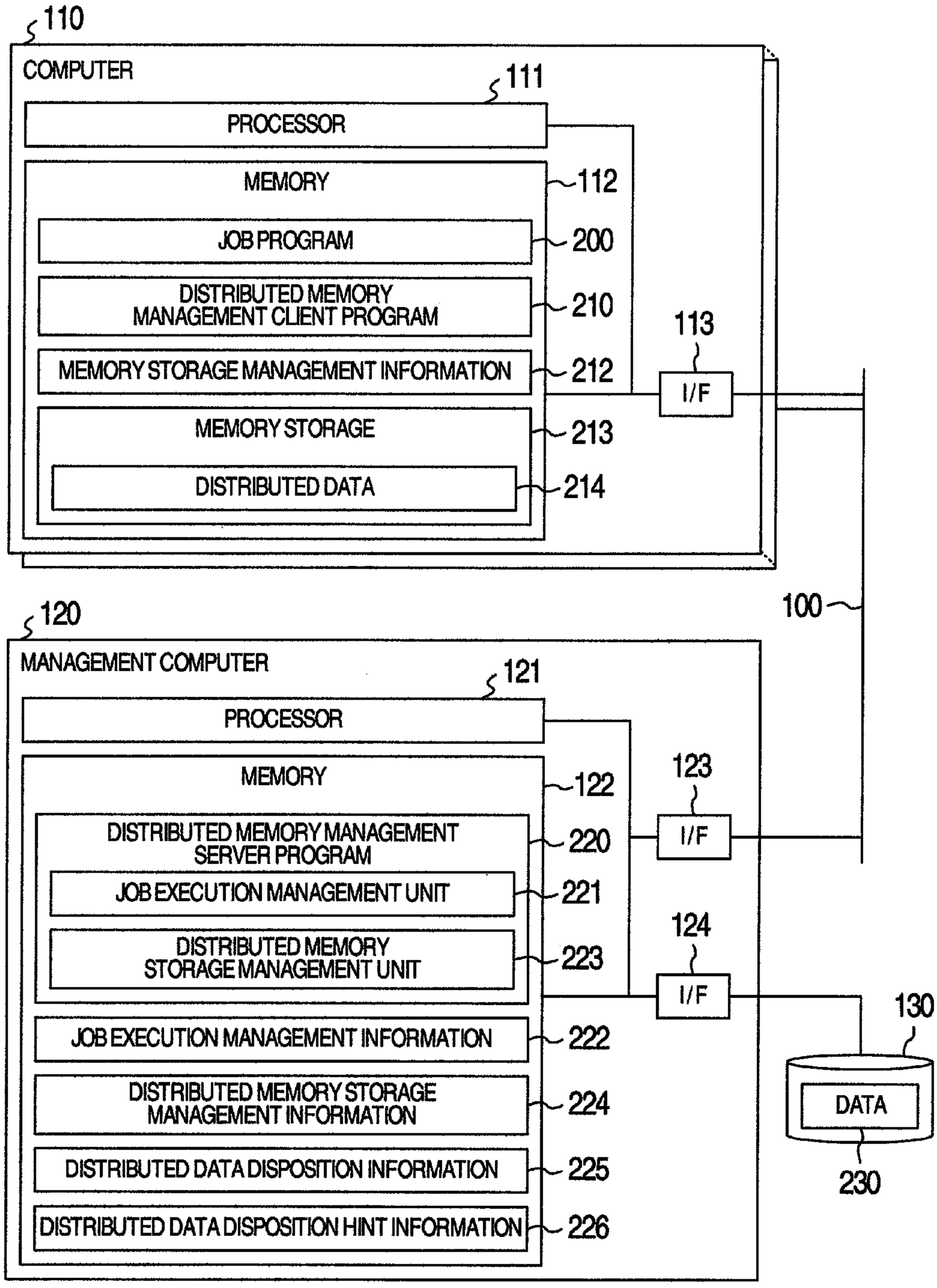

110
COMPUTER
111
PROCESSOR
MEMORY
112
JOB PROGRAM
200
DISTRIBUTED MEMORY MANAGEMENT CLIENT PROGRAM
210
MEMORY STORAGE MANAGEMENT INFORMATION
212
MEMORY STORAGE
213
DISTRIBUTED DATA
214
113
I/F
100
120
MANAGEMENT COMPUTER
121
PROCESSOR
MEMORY
122
DISTRIBUTED MEMORY MANAGEMENT SERVER PROGRAM
220
JOB EXECUTION MANAGEMENT UNIT
221
DISTRIBUTED MEMORY STORAGE MANAGEMENT UNIT
223
JOB EXECUTION MANAGEMENT INFORMATION
222
DISTRIBUTED MEMORY STORAGE MANAGEMENT INFORMATION
224
DISTRIBUTED DATA DISPOSITION INFORMATION
225
DISTRIBUTED DATA DISPOSITION HINT INFORMATION
226
123
I/F
124
I/F
130
DATA
230

FIG.2

212

300 DATA ID	310 RECORD LENGTH	320 DISTRIBUTION KEY	330 DISTRIBUTED DATA ID	340 DISTRIBUTION KEY RANGE	350 RECORD NUMBER	360 MEMORY ADDRESS
D0	100B	F0	D0_0	K0 - K99	600	0x1000 0000
			D0_1_1	K175 - K199	100	0x1004 0000
			D0_2_0	K200 - K244	100	0x1008 0000
D1	100B	F0	D1_0	K0 - K99	100	0x2000 0000
			D1_1_1	K175 - K199	25	0x2004 0000
			D1_2_0	K200 - K244	25	0x2008 0000
...	...	...	...	...	...	...

FIG.3

222

400 JOB ID	410 INPUT DATA ID	420 OUTPUT DATA ID	430 DISTRIBUTION NUMBER	440 COMPUTER ID	450 EXECUTION STATUS	460 RE-EXECUTION ID
J0	D0,D1	D2	3	C0	Running	—
				C1	Normal End	—
				C2	Abnormal End	RJ0_2
J1	D2	D3	3	C0	Waiting	—
				C1	Waiting	—
				C2	Waiting	—
...	...	...	...	...	...	...

FIG.4

500 RE-EXECUTION ID	510 DISTRIBUTION NUMBER	520 COMPUTER ID	530 EXECUTION STATUS
RJ0_2	2	C0	Waiting
		C1	Running
⋮	⋮	⋮	⋮

FIG.5

224

600 DISTRIBUTED MEMORY ID	610 COMPUTER NUMBER	620 COMPUTER ID	630 TOTAL MEMORY AREA	640 EMPTY MEMORY AREA
0	3	C0	8GB	7GB
		C1	8GB	7GB
		C2	8GB	7GB
1	3	C3	4GB	4GB
		C4	4GB	4GB
		C5	4GB	4GB
⋮	⋮	⋮	⋮	⋮

FIG.6

225

700 DATA ID	710 DISTRIBUTION NUMBER	720 DISTRIBUTION KEY
D0	3	F0
D1	3	F0
...	...	...

730 DISTRIBUTED DATA ID	740 DISTRIBUTION KEY RANGE	750 RECORD NUMBER	760 COMPUTER ID	770 REPLICA ID
D0_0	K0 - K99	600	C0	RD0_0
D0_1	K100 - K199	100	C1	RD0_1
D0_2	K200 - K299	100	C2	RD0_2
D1_0	K0 - K99	100	C0	RD1_0
D1_1	K100 - K199	25	C1	RD1_1
D1_2	K200 - K299	25	C2	RD1_2
...	...	...	...	...

FIG.7

800

REPLICA ID	DISTRIBUTION NUMBER
RD0_0	2
RD0_1	2
RD0_2	2
...	...

810

DISTRIBUTED DATA ID	DISTRIBUTION KEY RANGE	RECORD NUMBER
D0_0_0	K0-K49	300
D0_0_1	K50-K99	300
D0_1_0	K100-K174	300
D0_1_1	K175-K199	100
D0_2_0	K200-K224	100
D0_2_1	K225-K299	300
...	...	...

820 830 840

850

COMPUTER ID
C1
C2
C2
C0
C0
C1
...

FIG.8

226

900 DATA ID	910 DISTRIBUTION NUMBER	920 DISTRIBUTION KEY	930 DISTRIBUTION KEY RANGE	940 REDISTRIBUTION PROCESS PERMISSION	950 REPLICATION POLICY	960 REDISTRIBUTION RANGE	970 REJOINING PROCESS
D0	3	F0	K0 - K99	OK	Leveling	—	Merge + Sort
			K100 - K199	OK	Leveling	—	
			K200 - K299	OK	Leveling	—	
D1	3	F0	K0 - K99	OK	Leveling	—	Merge + Sort
			K100 - K199	OK	Leveling	—	
			K200 - K299	OK	Leveling	—	
...	...	...	...	...	...	...	...

FIG.9

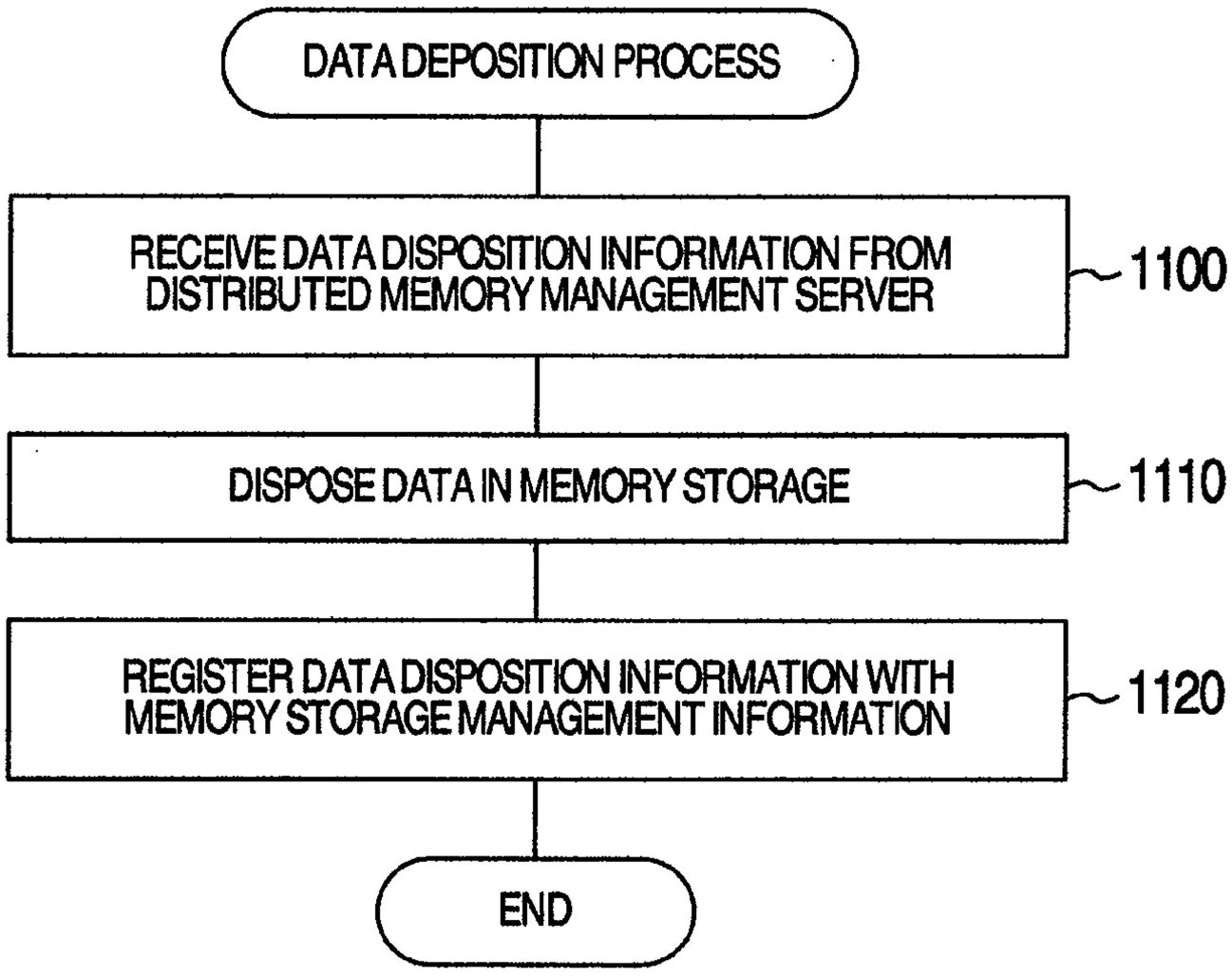

DATA DEPOSITION PROCESS
RECEIVE DATA DISPOSITION INFORMATION FROM DISTRIBUTED MEMORY MANAGEMENT SERVER
1100
DISPOSE DATA IN MEMORY STORAGE
1110
REGISTER DATA DISPOSITION INFORMATION WITH MEMORY STORAGE MANAGEMENT INFORMATION
1120
END

FIG.10

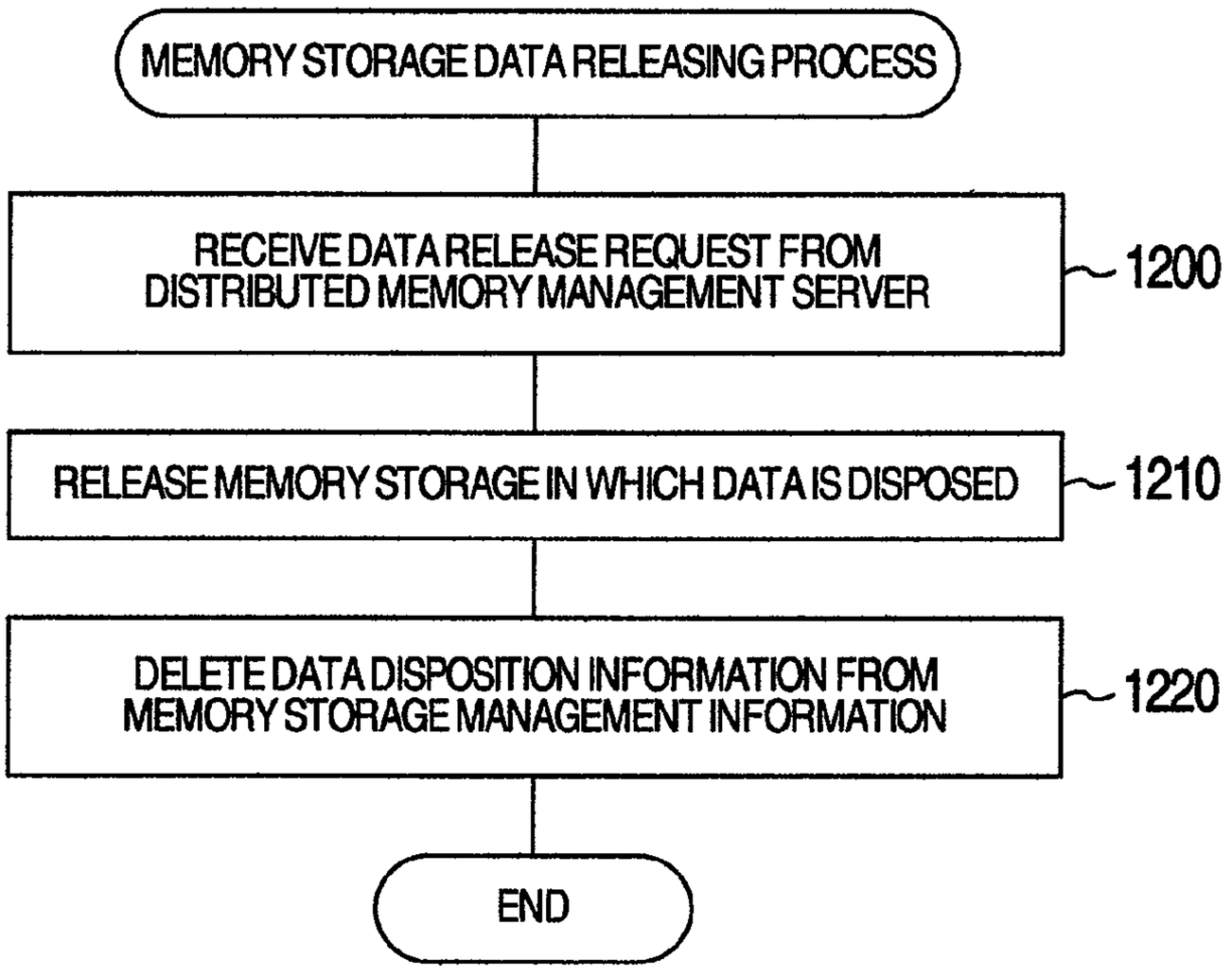

MEMORY STORAGE DATA RELEASING PROCESS
RECEIVE DATA RELEASE REQUEST FROM DISTRIBUTED MEMORY MANAGEMENT SERVER
1200
RELEASE MEMORY STORAGE IN WHICH DATA IS DISPOSED
1210
DELETE DATA DISPOSITION INFORMATION FROM MEMORY STORAGE MANAGEMENT INFORMATION
1220
END

FIG.11

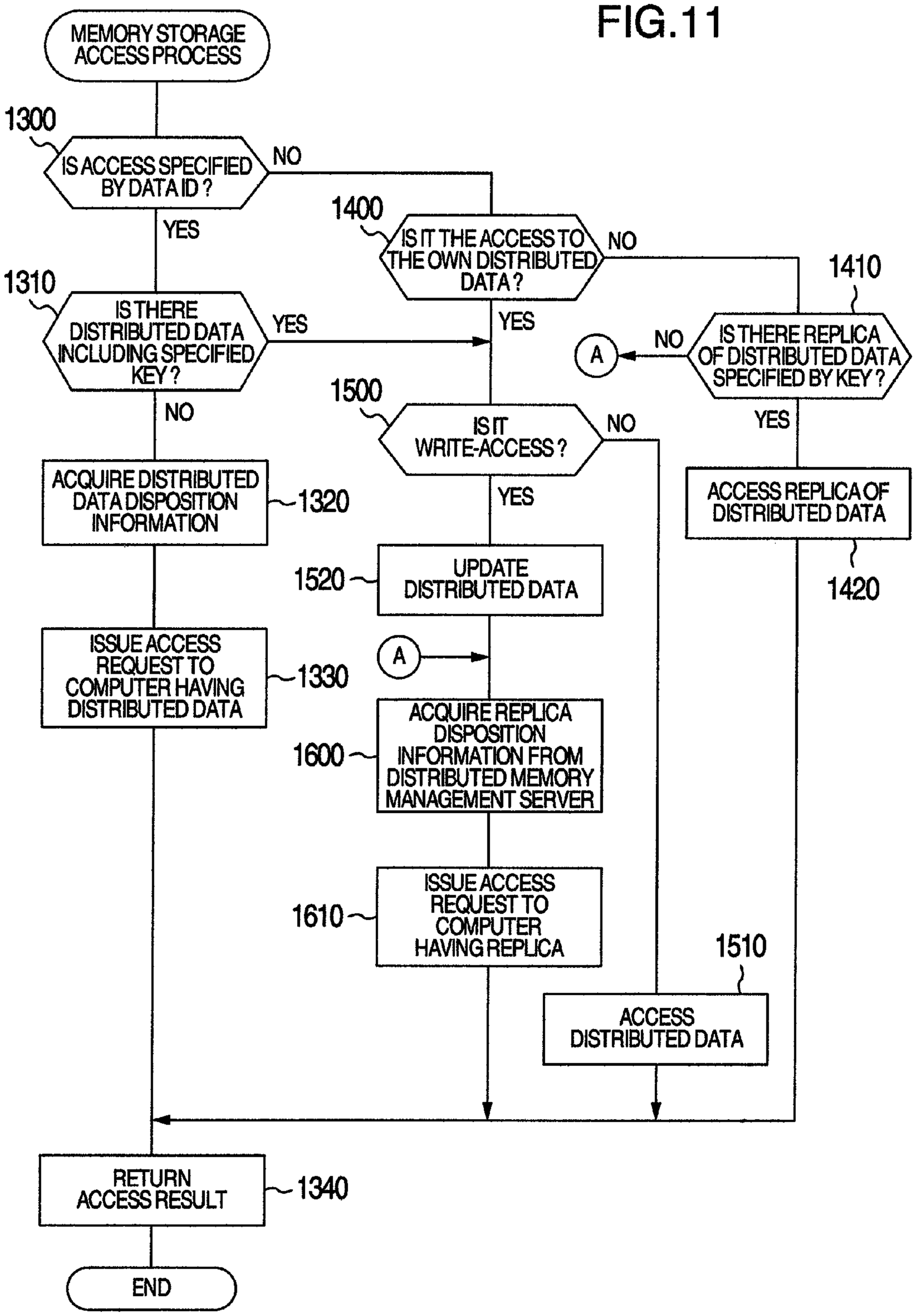

MEMORY STORAGE ACCESS PROCESS
1300
IS ACCESS SPECIFIED BY DATA ID ?
NO
YES
1400
IS IT THE ACCESS TO THE OWN DISTRIBUTED DATA ?
NO
1410
1310
IS THERE DISTRIBUTED DATA INCLUDING SPECIFIED KEY ?
YES
YES
A
NO
IS THERE REPLICA OF DISTRIBUTED DATA SPECIFIED BY KEY ?
1500
NO
IS IT WRITE-ACCESS ?
NO
YES
YES
ACQUIRE DISTRIBUTED DATA DISPOSITION INFORMATION
1320
ACCESS REPLICA OF DISTRIBUTED DATA
1520
UPDATE DISTRIBUTED DATA
1420
ISSUE ACCESS REQUEST TO COMPUTER HAVING DISTRIBUTED DATA
1330
A
1600
ACQUIRE REPLICA DISPOSITION INFORMATION FROM DISTRIBUTED MEMORY MANAGEMENT SERVER
1610
ISSUE ACCESS REQUEST TO COMPUTER HAVING REPLICA
1510
ACCESS DISTRIBUTED DATA
RETURN ACCESS RESULT
1340
END

FIG.12

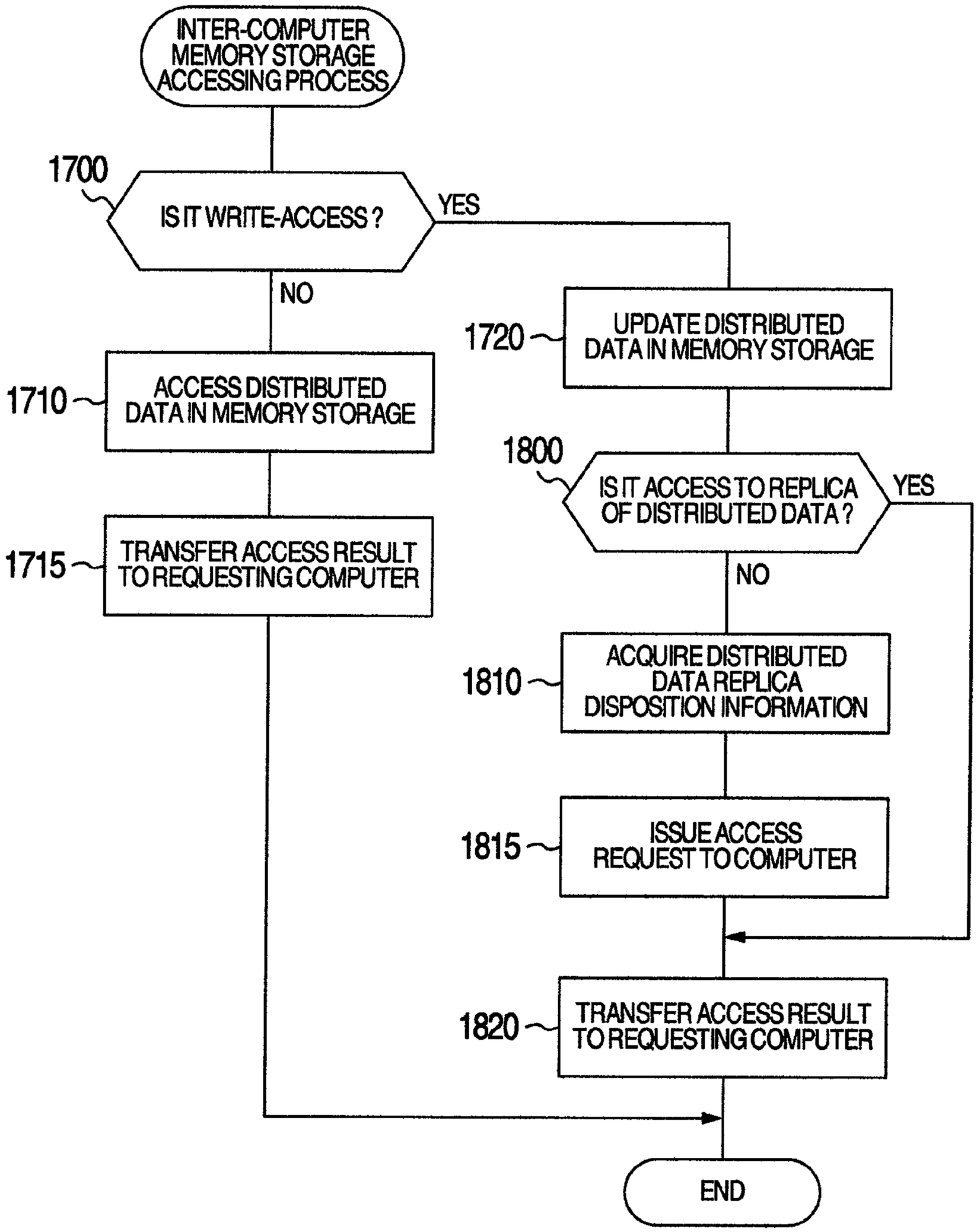

INTER-COMPUTER MEMORY STORAGE ACCESSING PROCESS
1700
IS IT WRITE-ACCESS ?
YES
NO
1710
ACCESS DISTRIBUTED DATA IN MEMORY STORAGE
1715
TRANSFER ACCESS RESULT TO REQUESTING COMPUTER
1720
UPDATE DISTRIBUTED DATA IN MEMORY STORAGE
1800
IS IT ACCESS TO REPLICA OF DISTRIBUTED DATA ?
YES
NO
1810
ACQUIRE DISTRIBUTED DATA REPLICA DISPOSITION INFORMATION
1815
ISSUE ACCESS REQUEST TO COMPUTER
1820
TRANSFER ACCESS RESULT TO REQUESTING COMPUTER
END

FIG.13

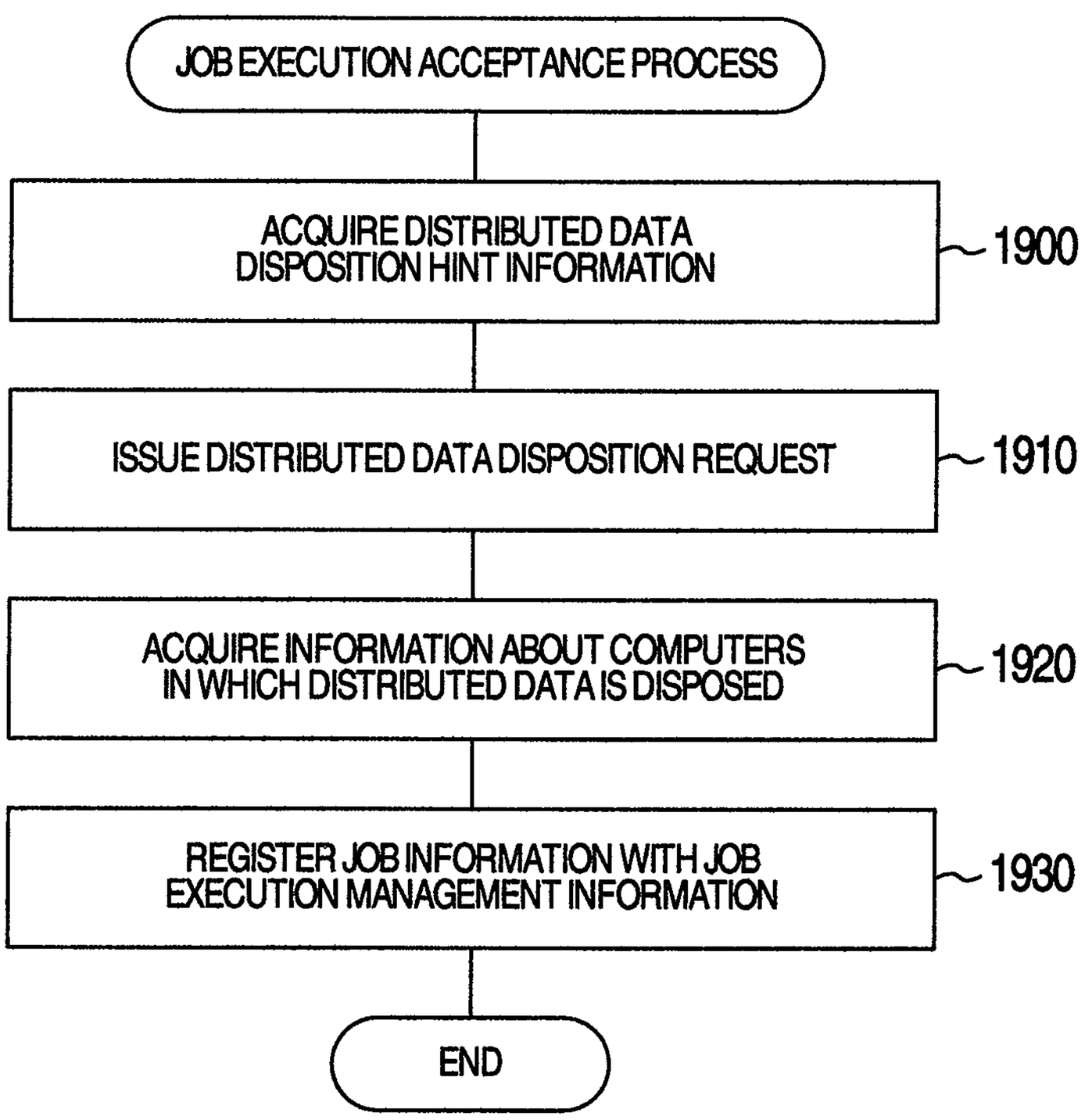

JOB EXECUTION ACCEPTANCE PROCESS
ACQUIRE DISTRIBUTED DATA DISPOSITION HINT INFORMATION
1900
ISSUE DISTRIBUTED DATA DISPOSITION REQUEST
1910
ACQUIRE INFORMATION ABOUT COMPUTERS IN WHICH DISTRIBUTED DATA IS DISPOSED
1920
REGISTER JOB INFORMATION WITH JOB EXECUTION MANAGEMENT INFORMATION
1930
END

FIG.14

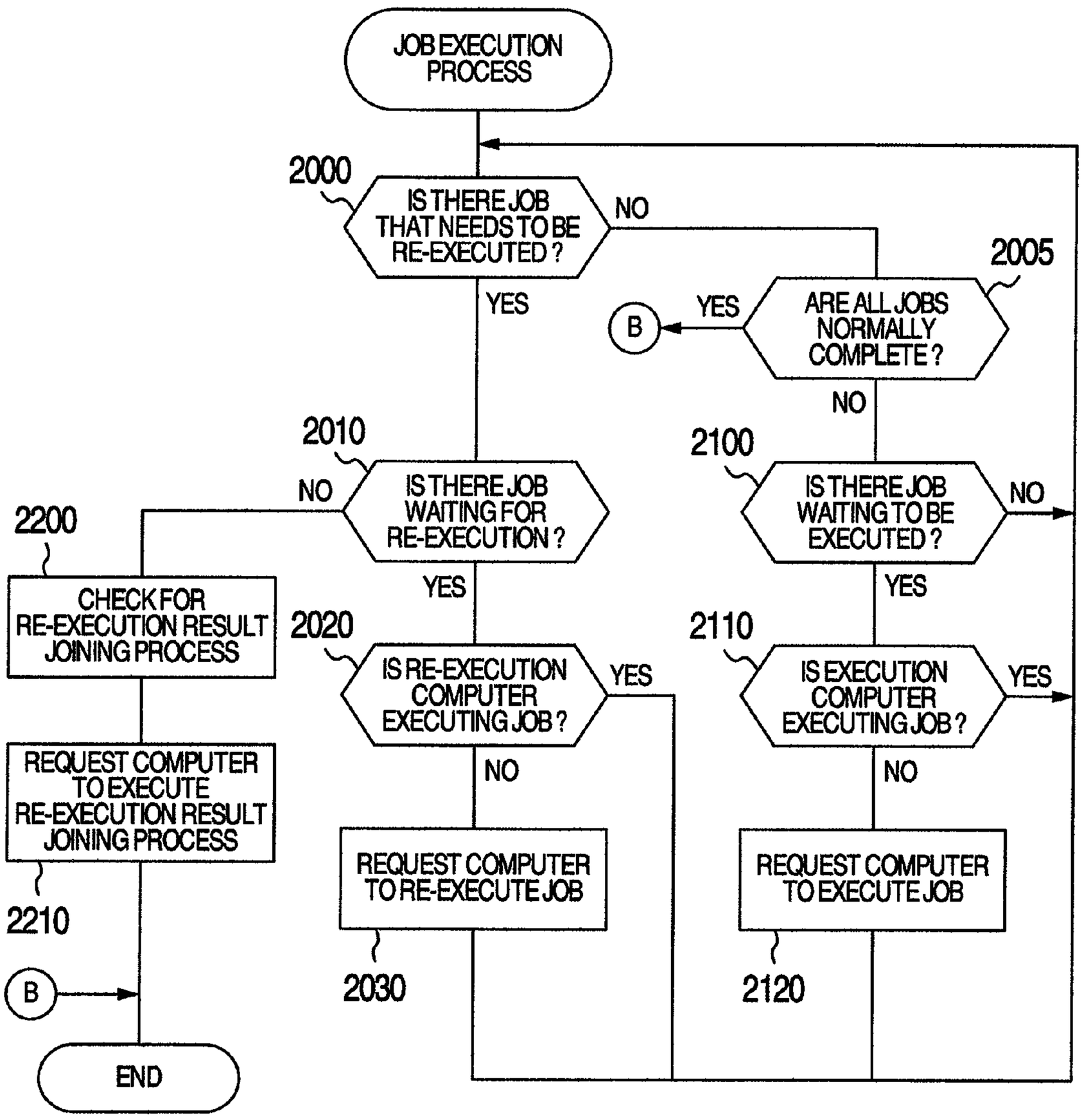

JOB EXECUTION PROCESS
2000
IS THERE JOB THAT NEEDS TO BE RE-EXECUTED?
NO
YES
2005
ARE ALL JOBS NORMALLY COMPLETE?
YES
B
NO
2010
IS THERE JOB WAITING FOR RE-EXECUTION?
NO
YES
2100
IS THERE JOB WAITING TO BE EXECUTED?
NO
YES
2200
CHECK FOR RE-EXECUTION RESULT JOINING PROCESS
2020
IS RE-EXECUTION COMPUTER EXECUTING JOB?
YES
NO
2110
IS EXECUTION COMPUTER EXECUTING JOB?
YES
NO
REQUEST COMPUTER TO EXECUTE RE-EXECUTION RESULT JOINING PROCESS
2210
REQUEST COMPUTER TO RE-EXECUTE JOB
2030
REQUEST COMPUTER TO EXECUTE JOB
2120
B
END

FIG.15

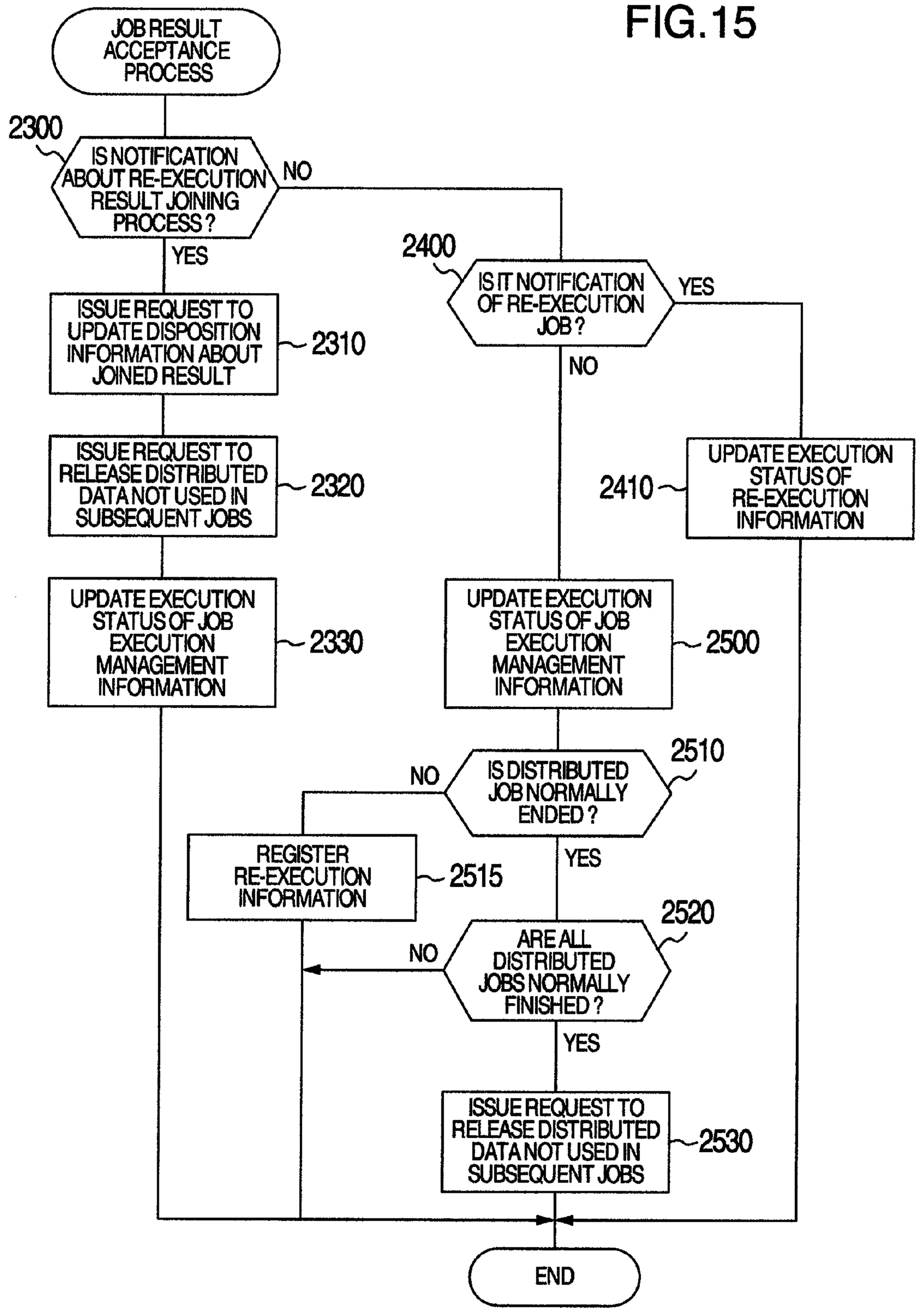

JOB RESULT ACCEPTANCE PROCESS
2300
IS NOTIFICATION ABOUT RE-EXECUTION RESULT JOINING PROCESS ?
NO
YES
ISSUE REQUEST TO UPDATE DISPOSITION INFORMATION ABOUT JOINED RESULT
2310
ISSUE REQUEST TO RELEASE DISTRIBUTED DATA NOT USED IN SUBSEQUENT JOBS
2320
UPDATE EXECUTION STATUS OF JOB EXECUTION MANAGEMENT INFORMATION
2330
2400
IS IT NOTIFICATION OF RE-EXECUTION JOB ?
YES
NO
2410
UPDATE EXECUTION STATUS OF RE-EXECUTION INFORMATION
UPDATE EXECUTION STATUS OF JOB EXECUTION MANAGEMENT INFORMATION
2500
2510
IS DISTRIBUTED JOB NORMALLY ENDED ?
NO
YES
REGISTER RE-EXECUTION INFORMATION
2515
2520
ARE ALL DISTRIBUTED JOBS NORMALLY FINISHED ?
NO
YES
ISSUE REQUEST TO RELEASE DISTRIBUTED DATA NOT USED IN SUBSEQUENT JOBS
2530
END

FIG.16

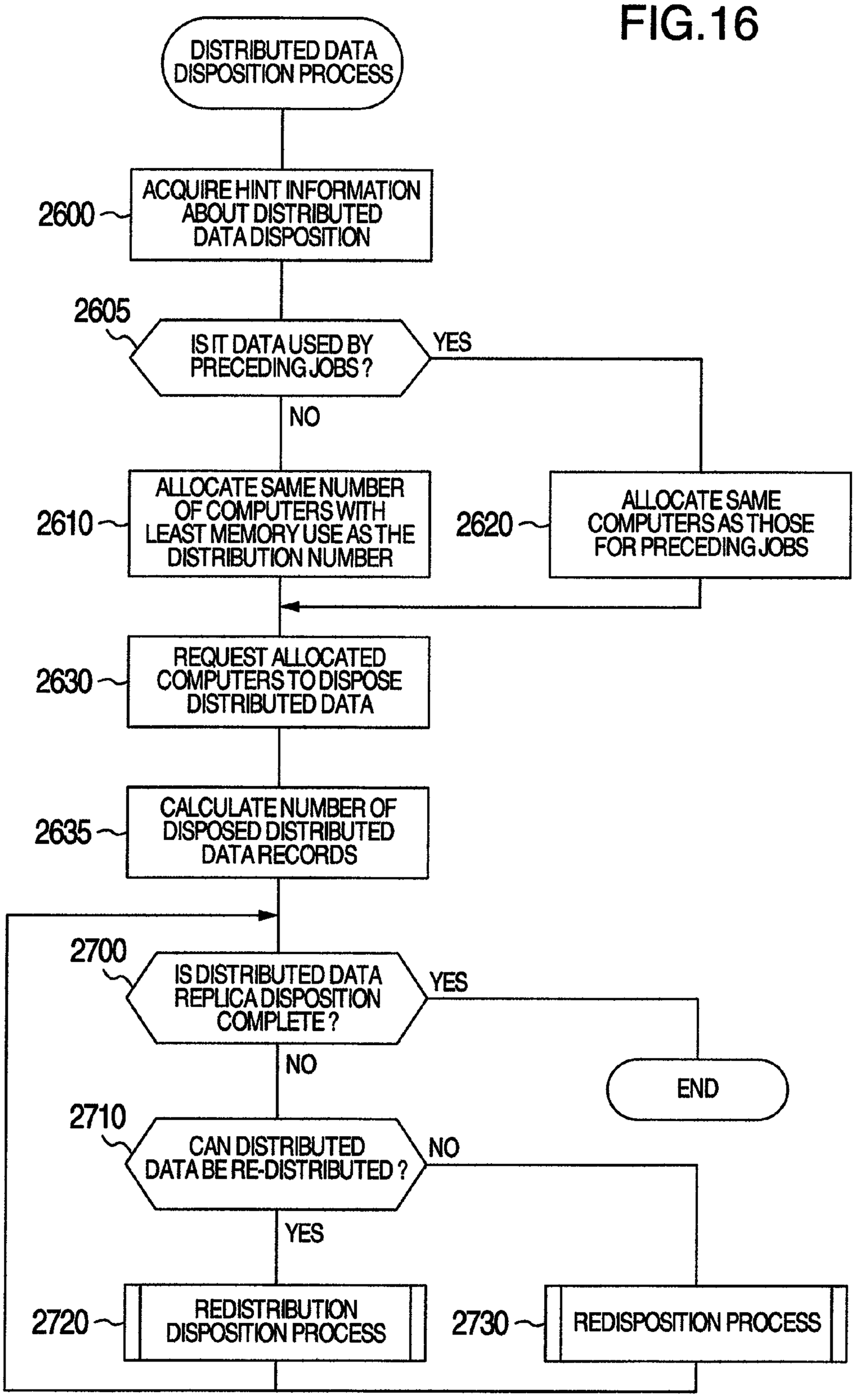

DISTRIBUTED DATA DISPOSITION PROCESS
2600
ACQUIRE HINT INFORMATION ABOUT DISTRIBUTED DATA DISPOSITION
2605
IS IT DATA USED BY PRECEDING JOBS ?
YES
NO
2610
ALLOCATE SAME NUMBER OF COMPUTERS WITH LEAST MEMORY USE AS THE DISTRIBUTION NUMBER
2620
ALLOCATE SAME COMPUTERS AS THOSE FOR PRECEDING JOBS
2630
REQUEST ALLOCATED COMPUTERS TO DISPOSE DISTRIBUTED DATA
2635
CALCULATE NUMBER OF DISPOSED DISTRIBUTED DATA RECORDS
2700
IS DISTRIBUTED DATA REPLICA DISPOSITION COMPLETE ?
YES
NO
END
2710
CAN DISTRIBUTED DATA BE RE-DISTRIBUTED ?
NO
YES
2720
REDISTRIBUTION DISPOSITION PROCESS
2730
REDISPOSITION PROCESS

FIG.17

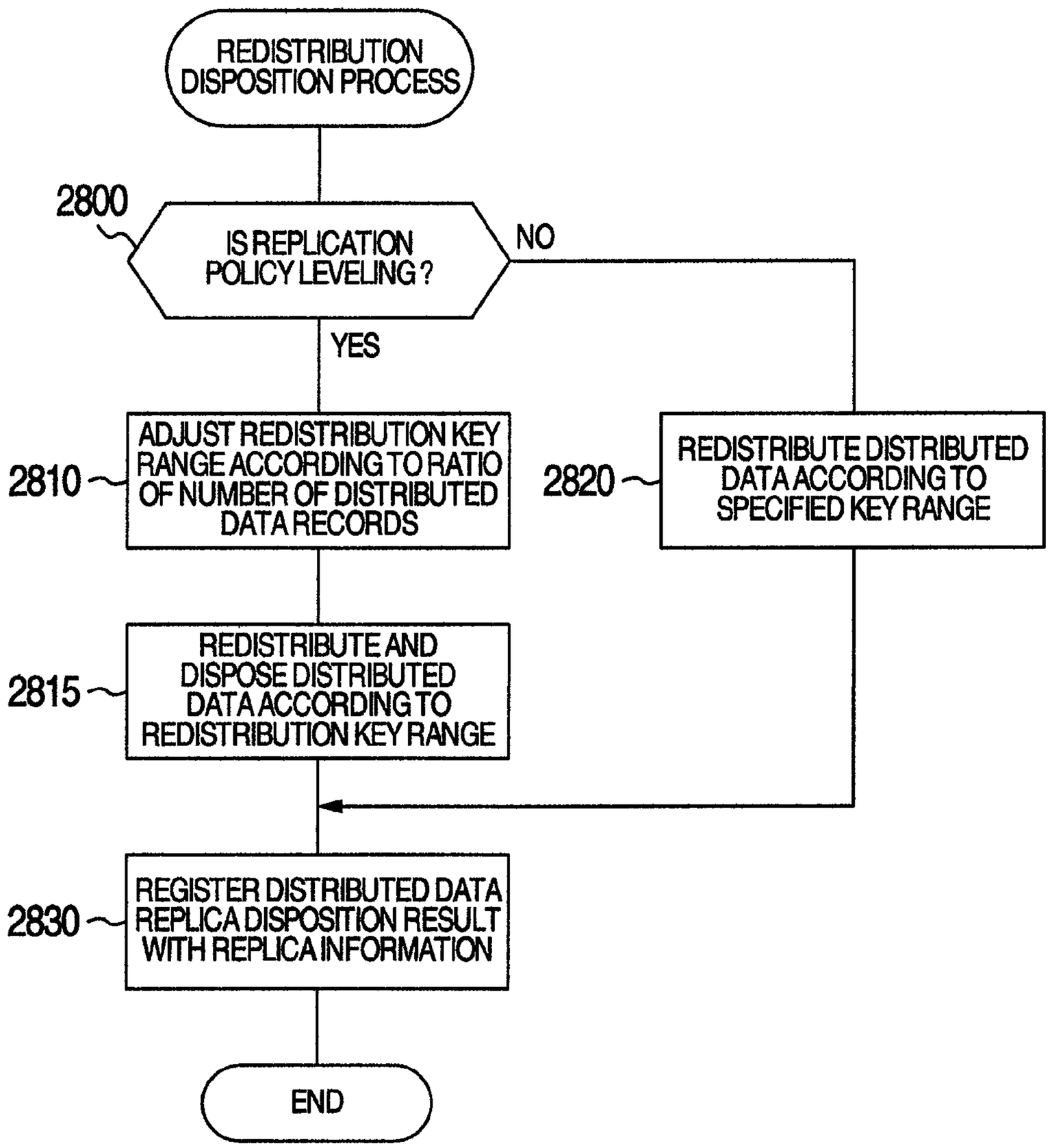

REDISTRIBUTION DISPOSITION PROCESS
2800
IS REPLICATION POLICY LEVELING ?
NO
YES
2810
ADJUST REDISTRIBUTION KEY RANGE ACCORDING TO RATIO OF NUMBER OF DISTRIBUTED DATA RECORDS
2820
REDISTRIBUTE DISTRIBUTED DATA ACCORDING TO SPECIFIED KEY RANGE
2815
REDISTRIBUTE AND DISPOSE DISTRIBUTED DATA ACCORDING TO REDISTRIBUTION KEY RANGE
2830
REGISTER DISTRIBUTED DATA REPLICA DISPOSITION RESULT WITH REPLICA INFORMATION
END

FIG.18

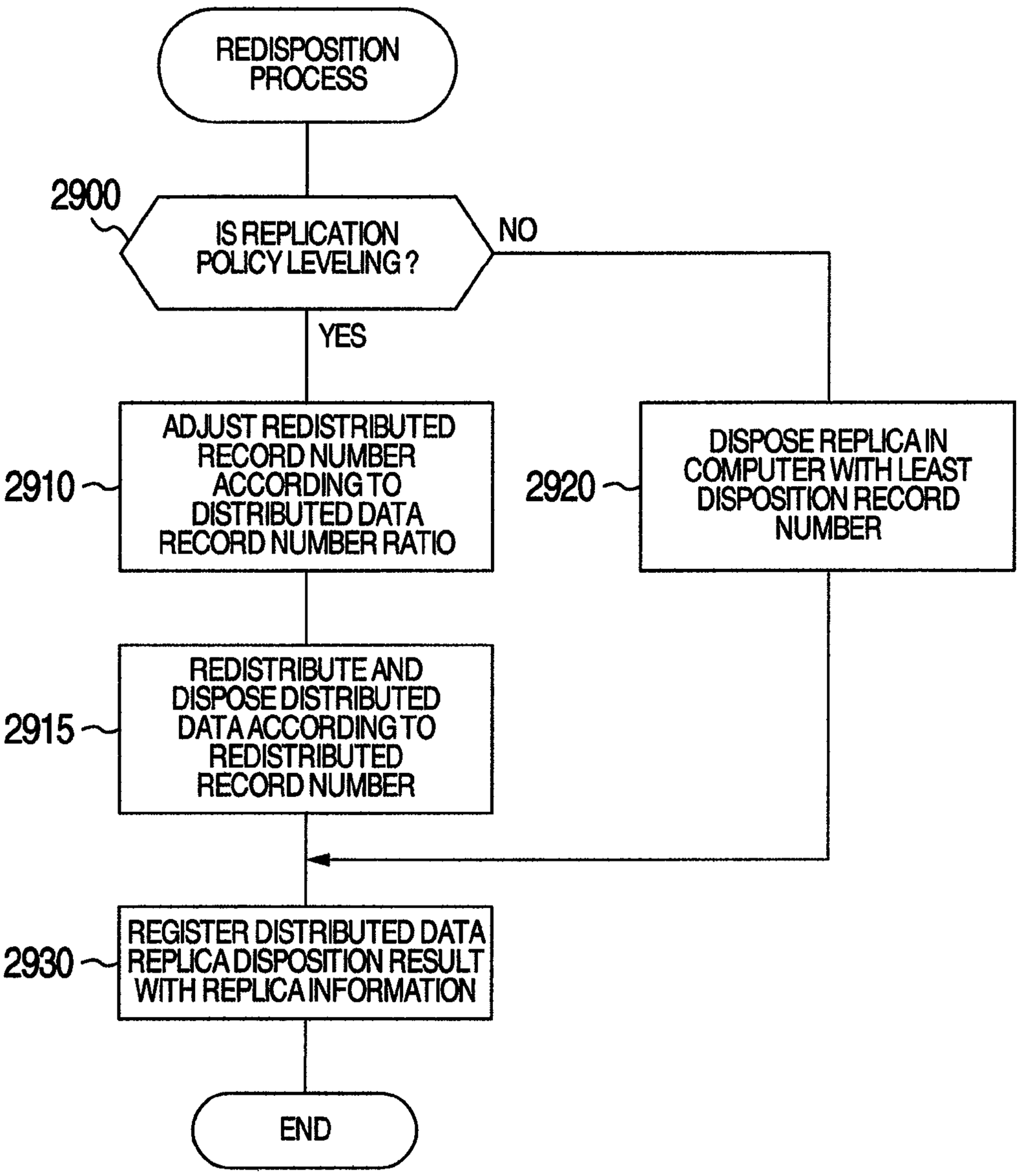

REDISPOSITION PROCESS
2900
IS REPLICATION POLICY LEVELING ?
NO
YES
2910
ADJUST REDISTRIBUTED RECORD NUMBER ACCORDING TO DISTRIBUTED DATA RECORD NUMBER RATIO
2920
DISPOSE REPLICA IN COMPUTER WITH LEAST DISPOSITION RECORD NUMBER
2915
REDISTRIBUTE AND DISPOSE DISTRIBUTED DATA ACCORDING TO REDISTRIBUTED RECORD NUMBER
2930
REGISTER DISTRIBUTED DATA REPLICA DISPOSITION RESULT WITH REPLICA INFORMATION
END

FIG.19

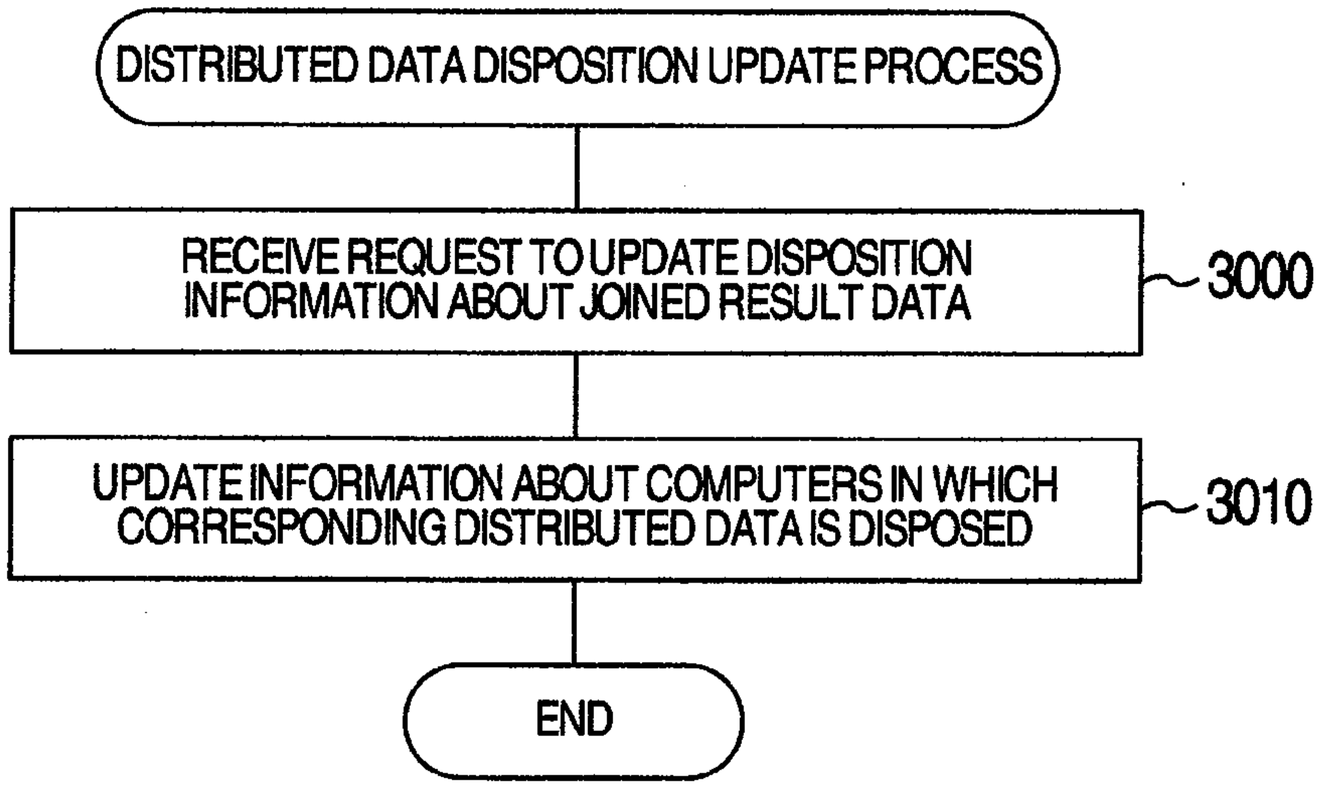

DISTRIBUTED DATA DISPOSITION UPDATE PROCESS
RECEIVE REQUEST TO UPDATE DISPOSITION INFORMATION ABOUT JOINED RESULT DATA
3000
UPDATE INFORMATION ABOUT COMPUTERS IN WHICH CORRESPONDING DISTRIBUTED DATA IS DISPOSED
3010
END

FIG.20

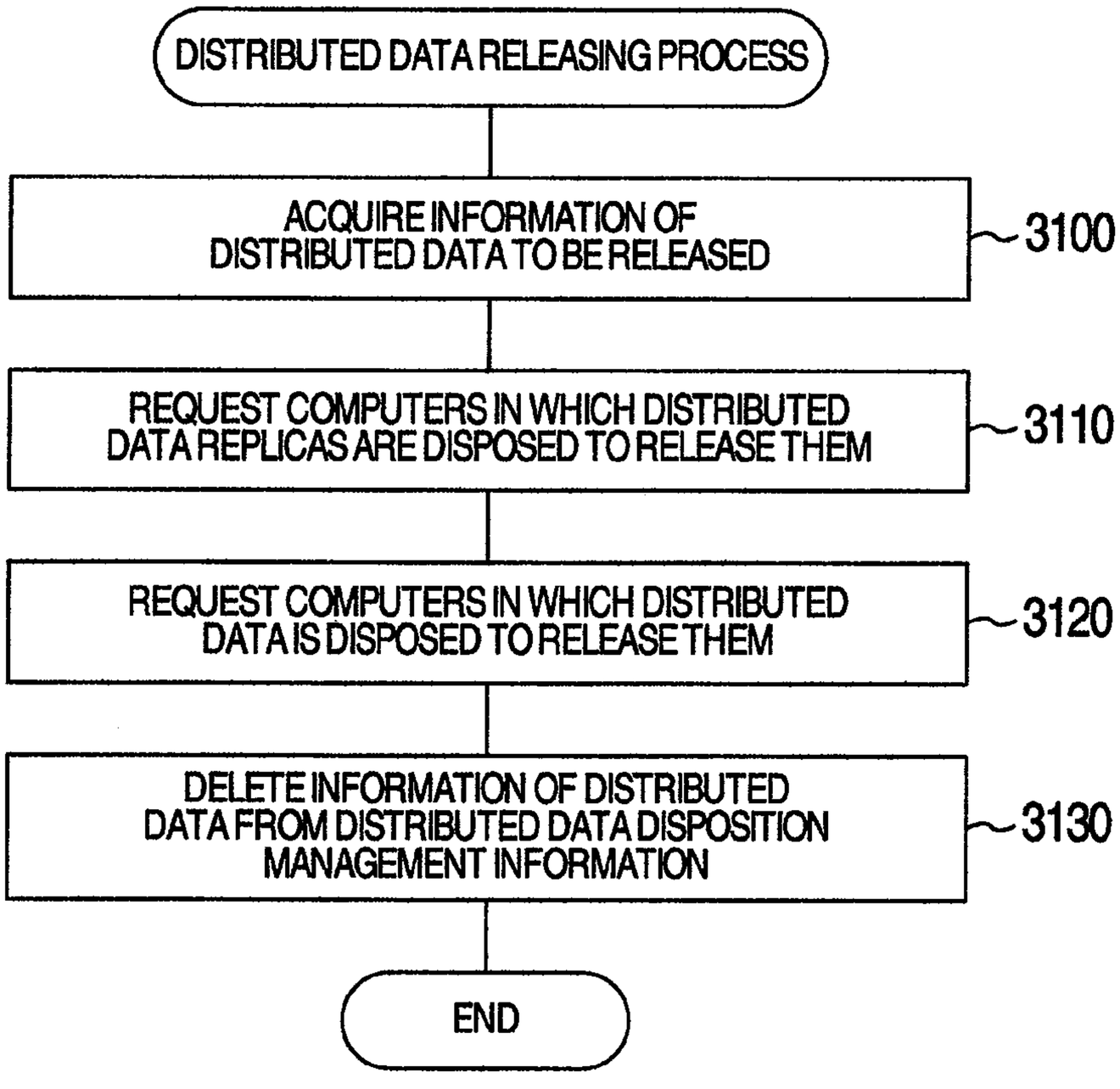
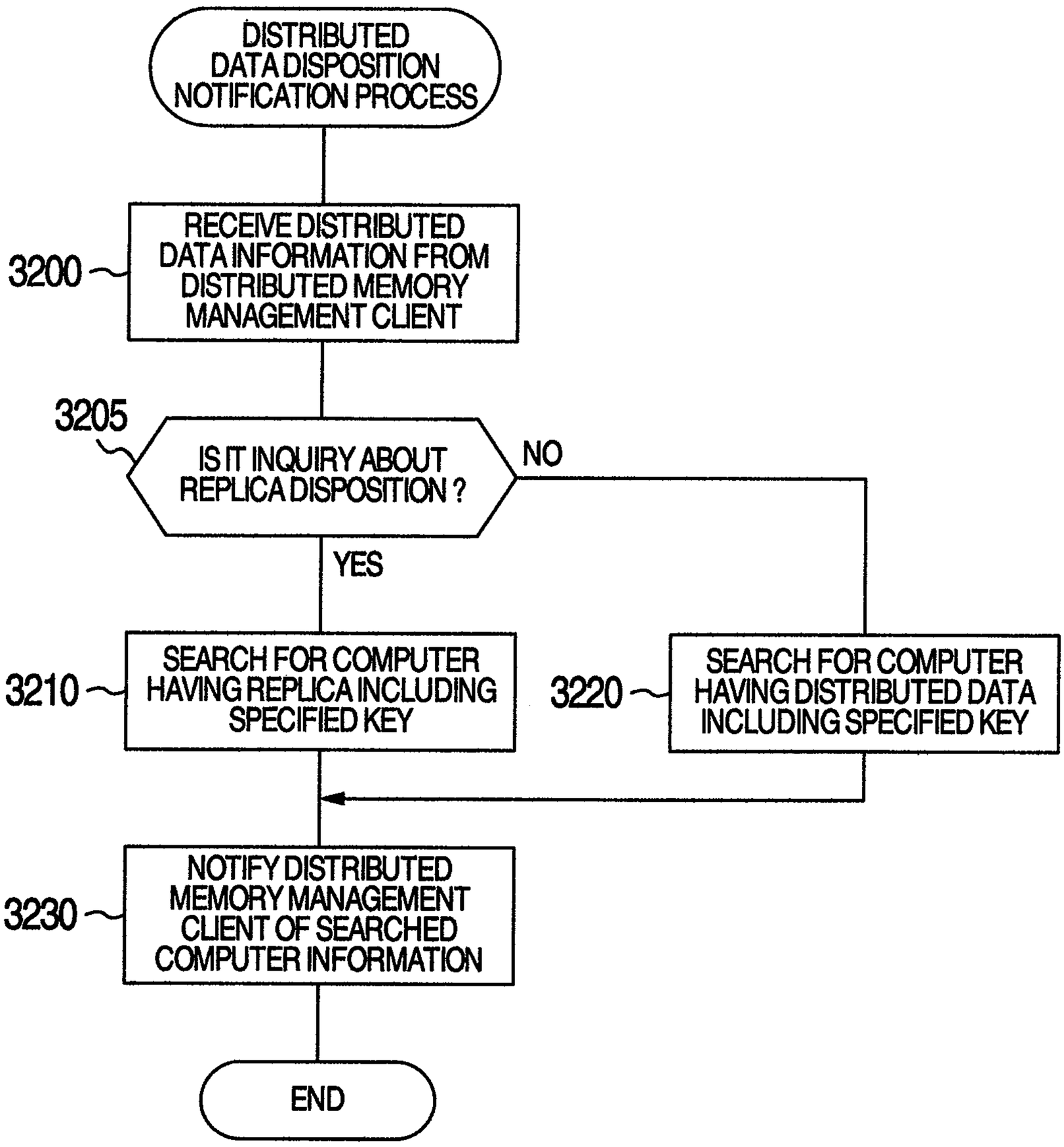

DISTRIBUTED DATA RELEASING PROCESS
ACQUIRE INFORMATION OF DISTRIBUTED DATA TO BE RELEASED
3100
REQUEST COMPUTERS IN WHICH DISTRIBUTED DATA REPLICAS ARE DISPOSED TO RELEASE THEM
3110
REQUEST COMPUTERS IN WHICH DISTRIBUTED DATA IS DISPOSED TO RELEASE THEM
3120
DELETE INFORMATION OF DISTRIBUTED DATA FROM DISTRIBUTED DATA DISPOSITION MANAGEMENT INFORMATION
3130
END

FIG.21


DISTRIBUTED DATA DISPOSITION NOTIFICATION PROCESS
3200
RECEIVE DISTRIBUTED DATA INFORMATION FROM DISTRIBUTED MEMORY MANAGEMENT CLIENT
3205
IS IT INQUIRY ABOUT REPLICA DISPOSITION ?
NO
YES
3210
SEARCH FOR COMPUTER HAVING REPLICA INCLUDING SPECIFIED KEY
3220
SEARCH FOR COMPUTER HAVING DISTRIBUTED DATA INCLUDING SPECIFIED KEY
3230
NOTIFY DISTRIBUTED MEMORY MANAGEMENT CLIENT OF SEARCHED COMPUTER INFORMATION
END

COMPUTER SYSTEM AND DATA PROCESSING METHOD FOR COMPUTER SYSTEM

INCORPORATION BY REFERENCE

The present application claims priority from Japanese application JP2010-220223 filed on Sep. 30, 2010, the content of which is hereby incorporated by reference into this application.

BACKGROUND OF THE INVENTION

The present invention relates to a computer system and a data processing method in the computer system and more particularly to a computer system for parallelly processing a large volume of data by a plurality of computers and a data processing method in the event of a fault.

In recent years, the volume of data processed by computer systems has been growing explosively. This in turn has increased the time taken by data processing, giving rise to a problem of a job failing to be finished within a predetermined time. To speed up data processing, it is increasingly necessary that a large volume of data be processed with a plurality of parallelly connected computers.

Among technologies for processing large volumes of data using a plurality of computers may be cited a distributed memory technology, like the one described in a document: GemStone Systems, Inc., "GemFireEnterprise," Technical White Paper, 2007. The distributed memory technology is a technology that integrates memories provided in a plurality of computers into one logical memory space in which to store data. In the distributed memory technology, since data is practically disposed distributed among memories of a plurality of computers, these distributed data can be processed by these computers parallelly. Further, since data is disposed in memories of the computers, data transfers to and from external storages such as disk drives are reduced. This in turn results in an increased speed of data processing.

The distributed memory technology, on the other hand, has a risk that, in the event of a fault in a computer, data held in that computer may be lost. To deal with this problem, it is a common practice in the distributed memory technology that the data held in the memory of a computer is replicated and that the replica of data is disposed in a memory of another computer to avoid a possible loss of data that would otherwise occur in the invent of a fault. When a fault has occurred in a computer, the operation that was being executed by that computer at the time of fault can be executed again by the second computer that holds the data replica. It is noted, however, that because the re-execution of the operation by the second computer in the event of a fault is done only after the second computer has finished the operation that was being executed at the time of fault, the completion of the overall data processing is delayed by the fault.

To speed up the re-execution of operation using the replicated data in the event of a computer fault, a technology is available to distributively dispose data in secondary memory devices of other computers, such as shown in JP-A-2000-322292 and JP-A-2001-100149. The technology disclosed in these patent documents has a replica of the data held by a computer distributively disposed in secondary memory devices of a plurality of other computers. When a fault occurs with a computer, a plurality of other computers with a secondary memory device holding the replica of the data held by the faulted computer parallelly process the data, thus reducing the time taken by the re-execution.

SUMMARY OF THE INVENTION

In distributing a large volume of data among a plurality of computers, the aforementioned conventional distributed memory technology uses specific information as a key, such as a name of stock to be traded. So, the volume of data held in a computer differs from one computer to another, depending on what information is used as a key in distributing data. Therefore, simply distributing a replica of data contained in each computer to different computers, as described in JP-A-2000-322292 and JP-A-2001-100149, can hardly level the data processing executed by individual computers, including the time taken by the re-execution.

The present invention has been accomplished with a view to overcoming the problem described above. That is, its objective is to level data processing, including a re-execution in the event of a fault, in a computer system that parallelly processes a large volume of data with a plurality of computers.

The above object and novel features of this invention will become apparent from the following description and the accompanying drawings.

Of the inventions disclosed in this application, representative ones may be briefly summarized as follows.

Viewed from one aspect the present invention provides a computer system having a storage device storing data, a plurality of first computers connected with the storage device and adapted to manage data processing using the data, and a plurality of second computers connected with the first computers and adapted to distributively execute the data processing. The first computers each have a distributive disposition unit and an execution management unit. The distributive disposition unit references given hint information indicating a policy of distributive disposition of the data in a plurality of the second computers, divides the data held in the storage device into a plurality of pieces of distributed data and distributively disposes the pieces of the distributed data and each piece of replicated data of the distributed data into memories of the plurality of the second computers. The execution management unit requests the second computers to execute the data processing and, in the event of a fault in any of the second computers, requests another second computer to re-execute the data processing that was being executed in the faulted second computer at the time of fault. The second computers each have a memory management unit and a data processing unit. The memory management unit holds the distributed data in a memory of its own computer in response to a request from the distributive disposition unit, and the data processing unit executes the data processing in response to a request from the execution management unit.

Another aspect of the present invention provides a data processing method in a computer system, wherein the computer system includes a plurality of first computers to distributively execute data processing, a second computer to manage the execution of the data processing by the plurality of the first computer, a storage device storing data used in the data processing, and a network interconnecting the plurality of the first computers, the second computer and the storage devices. According to hint information given to the second computer and indicating a policy on the distributive disposition of the data in the first computers, the data processing method divides the data held in the storage device into a plurality of pieces of distributed data and distributively disposes the distributed data and replicated data of each piece of

the distributed data in memories of the plurality of the first computers. It further performs data processing by the plurality of the first computers using the distributed data disposed in each of the first computers and, in the event of a fault in any of the first computers, re-executes the data processing, that was being executed in the faulted first computer at the time of fault, by another first computer that holds the replicated data of those distributed data disposed in the faulted first computer.

Of the inventions disclosed in this application, a representative one may briefly be summarized as follows.

In a computer system that parallelly processes a large volume of data with a plurality of computers, this invention can level the load of data processing, including the re-execution of job in the event of a fault, among the computers.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing an outline configuration of a computer system as one embodiment applying the present invention.

FIG. **2** is a conceptual diagram showing a data structure of memory storage management information **212** used to manage distributed data **214** disposed in a memory storage **213**.

FIG. **3** is a conceptual diagram showing a data structure of job execution management information **222**.

FIG. **4** is a conceptual diagram showing a structure of re-execution information.

FIG. **5** is a conceptual diagram showing a structure of distributed memory storage management information **224**.

FIG. **6** is a conceptual diagram showing a structure of distributed data disposition information **225**.

FIG. **7** is a conceptual diagram showing a structure of replica information.

FIG. **8** is a conceptual diagram showing a structure of distributed data disposition hint information **226**.

FIG. **9** is a flow chart of a process for disposing data into the memory storage **213**, performed by a distributed memory management client program **210**.

FIG. **10** is a flow chart of a memory storage data releasing process performed by the distributed memory management client program **210**.

FIG. **11** is a flow chart of a memory storage access process performed by the distributed memory management client program **210**.

FIG. **12** is a flow chart of an inter-computer memory storage accessing process.

FIG. **13** is a flow chart of a job execution acceptance process performed by a job execution management unit **221**.

FIG. **14** is a flow chart of a job execution process performed by the job execution management unit **221**.

FIG. **15** is a flow chart of a job result acceptance process performed by the job execution management unit **221**.

FIG. **16** is a flow chart of a distributed data disposition process performed by a distributed memory storage management unit **223**.

FIG. **17** is a flow chart of a redistribution disposition process.

FIG. **18** is a flow chart of a redisposition process.

FIG. **19** is a flow chart of a distributed data disposition update process performed by the distributed memory storage management unit **223**.

FIG. **20** is a flow chart of a distributed data releasing process performed by the distributed memory storage management unit **223**.

FIG. **21** is a flow chart of a distributed data disposition notification process performed by the distributed memory storage management unit **223**.

DESCRIPTION OF THE EMBODIMENTS

Now, embodiments of this invention will be described by referring to the accompanying drawings. In all the drawings identical members are basically assigned the same reference numerals and their repetitive explanations omitted.

FIG. **1** is a block diagram showing an outline configuration of an example computer system applying the present invention.

The computer system of this embodiment includes a plurality of computers **110** to execute jobs; a management computer **120** to manage the execution of jobs by the computers **110**; and a storage **130** in which to store data input to jobs executed by the computers **110** and data output from the executed jobs. The computers **110** are interconnected among them and also with the management computer **120** through a network **100**.

The computers **110** each have a processor **111** for computation, a memory **112** for storing programs and data, and an interface **113** for connecting the computer **110** to the network **100**.

The management computer **120** includes a processor **121** for computation, a memory **122** for storing programs and data, and an interface **123** for connecting the management computer **120** to the network **100** and an interface **124** for connecting it to the storage **130**.

In the memory **112** of each computer **110** there are stored a job program **200** that is executed by the processor **111** to do the job requested by the management computer **120** and a distributed memory management client program **210** to be executed by the processor **111** to manage the distributed memory made up of the memories **112** of the individual computers **110**. These programs do not need to be stored in the memory **112** at all times but may be stored in an external storage, such as a disk drive not shown, and read onto the memory **112** as needed for execution by the processor **111**.

In the memory **112** of each computer **110** the distributed memory management client program **210** described later allocates a memory storage **213** to build the distributed memory. These memory storages **213** are provided as one logical storage by the distributed memory management server program **220** and the distributed memory management client program **210**. In this specification this unified storage is called a distributed memory. Data to be stored in the distributed memory is distributed as distributed data **214** among the memory storages **213** allocated in the plurality of computers **110**. In the memory **112** of each computer **110** there is held memory storage management information **212** that the distributed memory management client program **210** in each computer uses to manage the distributed data **214** disposed in the memory storage **213**.

In the memory **122** of the management computer **120** there is stored a distributed memory management server program **220** that is executed by the processor **121** to manage the distributed memory made up of memories **112** of the plurality of computers **110**. The distributed memory management server program **220**, like the job program **200** and the distributed memory management client program **210**, may also be stored in an external storage not shown, read onto the memory **122** as needed and executed by the processor **121**.

The distributed memory management server program **220** has a job execution management unit **221** that manages jobs to be executed by the computers **110** and a distributed memory storage management unit **223** that, together with the distributed memory management client program **210**, manages the distributed memory. Also held in the memory **122** are job execution management information **222** used by the job execution management unit **221** to manage jobs executed by the plurality of computers **110**, distributed memory storage management information **224** and distributed data disposition information **225**, both of which are used by the distributed memory storage management unit **223** to manage the distributed memory and distributed data disposed in the distributed memory, and distributed data disposition hint information **226**.

In this embodiment, data **230** used for execution of jobs are managed in specified units, such as files, and stored in the storage **130**. The data **230** is read from the storage **130** before starting job executions and distributively disposed as distributed data **214** in the memory storages **213** in memories **112** of the individual computers **110**. In executing the jobs, the job program **200** on each of the computers **110** uses the distributed data **214** disposed in the memory storage **213** in its own computer **110**. When the job that was being executed by the computers **110** is completed, the distributed data **214** updated by the job are unified and stored as the data **230** in the storage **130**. In this embodiment, as described above, the job using the data **230** is executed distributively on a plurality of computers **110**.

In this embodiment the data **230** has a plurality of records. Each of the records includes at least one field holding values as data.

FIG. **2** is a conceptual diagram showing a data structure of the memory storage management information **212** used to manage the distributed data **214** disposed in the memory storage **213** allocated in the memory **112** of the computer **110** on which the distributed memory management client program **210** runs. In the diagram, while the memory storage management information **212** is shown in a table form, it can be implemented using any desired data structure, such as arrays and list structures, etc., that can relate different groups of information items. This also applies to other information described in the following.

The memory storage management information **212** includes: a data identifier (ID) **300** to identify the data **230** stored in the storage **130** that represents original data of the distributed data **214** disposed in the memory **112**; a record length **310** of each record making up the data; a distribution key **320**, an ID of the field used as a key in distributively disposing the data **230** in the distributed memory; a distributed data ID **330** that identifies the distributed data **214** disposed in the memory storage **213**; a distribution key range **340** included in each distributed data **214** identified by the distributed data ID **330** and representing the range of value in a field determined by the distribution key **320**; a record number **350** representing the number of records included in the distributed data **214** identified by the distributed data ID **330**; and a memory address **360** representing the location within the memory storage **213** of the distributed data **214** identified by the distributed data ID **330**.

When, in the memory storage management information **212** of FIG. **2**, the data with data ID "D0" is considered for example, it is seen that the data is made up of three groups of distributed data with a distribution key of "F0"—first group of 600 records in a key range of "K0-K99" with a distributed data ID of "D0_0", disposed in an area beginning at a memory address "0x10000000", a second group of 100 records in a key range of "K175-K199" with a distributed data ID of "D0_1_1", disposed in an area beginning at a memory address "0x10040000", and a third group of 100 records in a key range of "K200-K244" with a distributed data ID of "D0_2_0", disposed in an area beginning at a memory address "0x10080000". As described later, the distributed data with distributed data ID of "D0_1_1" and "D0_2_0" represent parts of replicas of those distributed data "D0" that are identified by distributed data ID "D0_1" and "D0_2" and disposed in other computers **110**.

FIG. **3** is a conceptual diagram showing a data structure of the job execution management information **222**.

The job execution management information **222** is used by the job execution management unit **221** to manage jobs that are distributively executed by a plurality of computers **110**. It includes a job ID **400** to identify each job; an input data ID **410** to identify the data **230** used as inputs for jobs; an output data ID **420** to identify data output as a job execution result; a distribution number **430** representing the number of computers **110** that distributively execute a job or the number of part jobs to be distributively executed; a computer ID **440** to identify the computers **110** that distributively execute a job; an execution status **450** representing the state of a job being distributively executed by the computers **110**; and a re-execution ID **460** to identify information on re-execution of a job in the event of a fault in the computer **110** that has been executing the job.

It is seen from the job execution management information **222** of FIG. **3** that job "J0" is one that takes in data "D0", "D1" as input data and outputs data "D2" and that it is distributively executed by three computers **110** with computer IDs "C0", "C1", "C2". In the execution status **450** the following information indicating the status of job execution is set for each of the computers involved in distributively executing the job: "Running" indicating that the job allocated to the computer is being executed; "Normal End" indicating the job has ended normally; "Abnormal End" indicating the job has ended abnormally due to a fault in the computer; and "Waiting" indicating that the job is waiting to be executed.

FIG. **4** is a conceptual diagram showing a structure of re-execution information.

The re-execution information **460** is used by the job execution management unit **221** to manage the statuses of jobs to be re-executed (hereinafter referred to as re-execution jobs) when a job that was being executed in one of the computers **110** at time of fault is re-executed by another computer **110**. The re-execution information includes a re-execution ID **500** to identify a re-execution job, a distribution number **510** for a re-execution job identified by the re-execution ID **500**, a computer ID **520** to identify the computer to which a re-execution job is assigned, and execution status information **530** representing the execution status of the re-execution job allocated to each computer.

The distribution number **510** in this embodiment represents the number of computers that distributively execute the re-execution jobs identified by the re-execution ID **500**, For one re-execution ID **500**, the same number of computer IDs **520** as that specified by the distribution number **510** and the execution status information **530** are set. The re-execution ID **500** corresponds to the re-execution ID **460** for the job execution management information **222**. The execution status of the re-execution job associated with a specific job can be managed using the re-execution information in which the same re-execution ID as the re-execution ID **460** is set. Thus by referring to FIG. **3** and FIG. **4**, it is understood that the re-execution job "RJ0_2" of a job that was a part of the job "J0" and which was being executed by the computer "CT" is

to be distributively executed by two computers **110** "C0", "C1", with the re-execution job in the computer "C0" in the "Waiting" state and the re-execution job in the computer "C1" in the "Running" state or being executed.

In this embodiment the re-execution information is supposed to be held in the memory **122** as information accompanying the job execution management information **222**. Although in this embodiment the job managed by the job execution management information **222** and the re-execution information on the re-execution job associated with the job are related with each other by the re-execution IDs **460**, **500**, they may be associated by using pointer information leading to the associated re-execution information, instead of the re-execution ID **460**, or by directly holding the re-execution information as part of the job execution management information **222**.

FIG. **5** is a conceptual diagram showing a structure of the distributed memory storage management information **224**.

The distributed memory storage management information **224** is used by the distributed memory storage management unit **223** to manage the distributed memory composed of memories of a plurality of computers **110**. In this embodiment, the distributed memory storage management unit **223** can build a plurality of distributed memory storages. The distributed memory storage management information **224** includes a distributed memory ID **600** to identify individual distributed memory storages, a computer number **610** representing the number of computers **110** used in forming the distributed memory identified by the distributed memory ID **600**, a computer ID **620** of each of the computers **110** used to build the distributed memory, a total memory area information **630** indicating a total memory capacity of the distributed memory, and empty memory area information **640** representing a memory capacity in the distributed memory that is available for use.

Referring to the distributed memory storage management information **224** in FIG. **5**, the distributed memory identified by distributed memory ID "0", for example, is made up of areas on the memories **112** in those computers **110** identified by the computer IDs "C0", "C1" and "C2", each with a total memory capacity of 8 GB and an empty memory area of 7 GB.

FIG. **6** is a conceptual diagram showing a structure of the distributed data disposition information **225**.

The distributed data disposition information **225** is used by the distributed memory storage management unit **223** to manage the disposition of data in the distributed memory. It includes a data ID **700** to identify data **230** which constitutes the original of distributed data **214** disposed distributively in the memories **112** of a plurality of computers **110**; a distribution number **710** representing the number of pieces of data **230** distributively disposed in the memories **112** of the computers, i.e., the number of divided pieces of data **230** or the number of pieces of distributed data **214** after data division; a distribution key **720** to identify a field used as a key when dividing the data **230** into distributed data **214**; a distributed data ID **730** to identify each piece of distributed data; a distribution key range **740** representing a range of value that the field specified by the distribution key **720** holds in each piece of distributed data; a record number **750** representing the number of records included in each piece of distributed data; a computer ID **760** of a computer **110** in which each piece of distributed data is disposed; and a replica ID **770** representing information on a replica of distributed data used during the re-execution of a job.

Referring to the distributed data disposition information **225** shown in FIG. **6**, it is understood that data "D0" is divided into three pieces of distributed data with a field "F0" taken as a distribution key and is distributively disposed in computers "C0", "C1" and "C2". The three groups of distributed data are each assigned a distributed data ID **730** "D0_0", "D0_1", "D0_2" and respectively include 600 records in a field "F0" of "K0-K99", 100 records in a field of "K100-K199" and 100 records in a field of "K200-K299". It is also understood that the replica information about replicated data of each group of distributed data is represented by a replica ID "RD0_0", "RD0_1", "RD0_2".

FIG. **7** is a conceptual diagram showing a structure of replica information. In this embodiment a replica of distributed data (hereinafter referred to as replicated data) is further divided and distributively disposed in a plurality of computers **110** other than those in which original distributed data is disposed. In the following, a portion of replicated data disposed in one computer is referred to as partial replicated data.

The replica information includes information about a plurality of pieces of replicated data. The replica information about each piece of replicated data includes a replica ID **800** to identify the replica information; a distribution number **810** representing the number of computers in which to dispose replicated data; a distributed data ID **820** to identify partial replicated data distributively disposed in computers; a distribution key range **830** indicating the range of data included in the partial replicated data identified by the distributed data ID **820**; a record number **840** representing the number of records included in the partial replicated data identified by the distributed data ID **820**, and a computer ID **850** representing the computer **110** in which each piece of partial replicated data is disposed.

In FIG. **7** replica information "RD0_0", for example, is shown to have its replicated data distributively disposed in two computers and to comprise two pieces of partial replicated data that are assigned distributed data ID "D0_0_0" and "D0_0_1". It is also seen that the partial replicated data "D0_0_0" includes 300 records in a distribution key range of "K0-K49" and is disposed in a computer "C1" and that the partial replicated data "D0_0_1" includes 300 records in a distribution key range of "K50-K99" and is disposed in a computer "C2". Reference to the distributed data disposition information **225** of FIG. **6** reveals that the replica information "RD0_0" is information about the replicated data of the distributed data "D0_0", a part of the data "D0".

In this embodiment the replica information is supposed to be held in the memory **122** as information accompanying the distributed data disposition information **225**. Further, although in this embodiment the distributed data and the replica information about the replicated data are related to each other by the replica ID **770**, **800**, they may be related by using pointer information leading to the associated replica information, instead of the replica ID **770**, or by holding the replica information as part of the distributed data disposition information **225**.

FIG. **8** is a conceptual diagram showing a structure of the distributed data disposition hint information **226**.

The distributed data disposition hint information **226** includes a data ID **900** of data **230** to be distributively disposed; a distribution number **910** representing the number of computers **110** in which the data **230** is distributively disposed, i.e., the number of divided pieces of data **230** or the number of pieces of distributed data **214** after data division; a distribution key **920** to identify a field used as a key when dividing the data **230**; a distribution key range **930** representing a range of value held in a field that is used as a key for distributed data **214** when distributively disposing the data **230**; a redistribution process permission **940** indicating

whether, during the process of making a replica of distributed data for re-execution of a job, the replica of distributed data can further be distributed for processing; a replication policy **950** representing a policy when duplicating the distributed data; a redistribution range **960** specifying a range of data in which, during the process of making a replica of distributed data, the replica of the distributed data is further distributed; and a rejoining process information **970** specifying a method of processing those data written into the memory storages **213** of the computers **110** which have been acquired as a result of using the replica of distributed data and re-executing the job **200** in the event of a fault in a computer **110**.

The information set as the replication policy **950** includes "leveling" which, in making a replica of distributed data, demands the leveling of processing load among computers that participate in performing the re-execution job during the job re-execution process and "fixed key range" that specifies in advance the range of value in the fields designated by the distribution key **920**. If the replication policy **950** is set with the "fixed key range", the range of value in the fields designated by the distribution key **920**, which is used in dividing the distributed data, is set in the redistribution range **960** for each piece of distributed data.

The rejoining process information **970** may include information specifying merge and sort operations to be performed on those data output to the memory storages **213** of computers **110** as a result of distributing and executing the job **200**. The rejoining process information **970** may also be configured to accept other processing, such as a statistics operation that stacks output data or an operation prepared by the user. The execution of the operation designated here now can produce the same distributed data as the one that would be acquired by executing a job on the original distributed data.

FIG. **9** is a flow chart of a process performed by the distributed memory management client program **210** in disposing data in the memory storage **213** in this embodiment.

In the data disposition process, the distributed memory management client program **210** accepts information about the disposition of the distributed data **214** from the distributed memory management server program **220** of the management computer **120** (step **1100**). The distributed memory management client program **210**, according to the received disposition information about the distributed data **214**, disposes the distributed data **214** in the memory storage **213** in the memory **122** of its own computer **110** (step **1110**). After disposing the distributed data **214** in the memory storage **213**, the distributed memory management client program **210** registers with the memory storage management information **212** the received disposition information about the distributed data **214** and the address in the memory storage **213** at which the distributed data **214** is disposed (step **1120**).

FIG. **10** is a flow chart of a memory storage data releasing process performed by the distributed memory management client program **210** in this embodiment. The memory storage data releasing process is executed to release the memory storage **213** of the distributed data **214** so that it can be used for storing other data.

In the memory storage data releasing process, the distributed memory management client program **210** first receives from the distributed memory management server program **220** in the management computer **120** a release request as distributed data release information which contains an ID of the distributed data **214** to be released (step **1200**). The distributed memory management client program **210**, according to the received release information about the distributed data **214**, releases the memory storage **213** in which the distributed data **214** is disposed (step **1210**). After this, the distributed memory management client program **210** deletes from the memory storage management information **212** the disposition information about the distributed data **214** held in the released memory storage **213** (step **1220**).

FIG. **11** is a flow chart of a memory storage access process performed by the distributed memory management client program **210** in response to a request from the job program **200** in this embodiment.

The job program **200**, when it accesses the data **230** in executing a job, issues an access request, which contains an ID of the data **230** and a key in the record that it is going to access, to the distributed memory management client program **210** in its own computer **110**. The key in this case is a value of the field specified by the distribution key **320**. If the access request is to the distributed data, an ID of the distributed data of interest is designated instead of the ID of the original data **230**. Upon receiving the access request, the distributed memory management client program **210** references the memory storage management information **212** to check whether the received access request specifies the ID of the original data **230** for the distributed data **214** held in the memory storage **213** of its own computer **110** (step **1300**).

If at step **1300** the access request is found to specify the ID of the original data **230**, the distributed memory management client program **210** refers to the memory storage management information **212** to see if the distributed data **214** including the key specified by the access request is held in the memory **112** (step **1310**).

If at step **1310** it is decided that the distributed data **214** including the specified key is not held in the memory **112**, the distributed memory management client program **210** queries the distributed memory management server program **220** in the management computer **120** to acquire information about the computer **110** holding the distributed data **214** including the specified key (step **1320**). When it acquires information about the computer **110** holding the distributed data **214** of interest from the distributed memory management server program **220**, the distributed memory management client program **210** issues an access request including the specified key and the ID of the distributed data **214** containing that key to a distributed memory management client program **210** in the computer **110** in question (step **1330**). Then, the distributed memory management client program **210** in the request issued computer **110** receives from the computer **110** holding the distributed data **214** of interest a record corresponding to the value of the specified key, obtained as a result of accessing the distributed data **214** containing the specified key, and returns the record to the job program **200** (step **1340**).

If step **1300** decides that the access request does not specify the ID of the original data **230**, i.e., the access request specifies the ID of distributed data, the distributed memory management client program **210** refers to the memory storage management information **212** to check if the access request is to the distributed data **214** held in the memory **112** of its own computer **110** (step **1400**).

If the access request is for the distributed data of the original data **230** not held in the memory **112** of its own computer **110**, the access request is one for a replica of the distributed data **214** held in the memory storage **213** of other computer **110**. In this case, the distributed memory management client program **210** refers to the memory storage management information **212** checks whether the replica of the distributed data including the key specified by the access request from the job program **200** is held in the memory **112**. If the replica of the distributed data containing the specified key is found not held in the memory **112**, the distributed memory management client program **210** proceeds to step **1600** (step **1410**).

If at step **1410** the replica of the distributed data containing the specified key is found held in the memory **112**, the distributed memory management client program **210** refers to the memory storage management information **212** and accesses the address in the memory storage **213** where the replica of the distributed data of interest is held (step **1420**). Then, the distributed memory management client program **210** receives the result of access to the replica of distributed data and returns it to the job program **200** (step **1340**).

If step **1400** decides that the access request is for the distributed data of the original data **230** held in the memory **112**, the distributed memory management client program **210** checks whether the access is a write access or not (step **1500**).

If the access request from the job program **200** is found not to be a write access, the distributed memory management client program **210** refers to the memory storage management information **212** and accesses the address in the memory storage **213** where the distributed data of interest is held (step **1510**). Then the distributed memory management client program **210** receives the result of access to the distributed data and returns it to the job program **200** (step **1340**).

If, on the other hand, step **1500** decides that the access request from the job program **200** is a write access, the distributed memory management client program **210** refers to the memory storage management information **212** and updates a record at the address in the memory storage **213** where the distributed data is held.

Next, the distributed memory management client program **210** queries the distributed memory management server program **220** of the management computer **120** and acquires information about a computer **110** in which a replica of the distributed data including the key specified by the access request is disposed (step **1600**). Then, the distributed memory management client program **210**, based on the information acquired from the distributed memory management server program **220**, requests the computer **110** of interest to access the replica of distributed data including the key specified by the access request. This access request includes an ID of the replica of distributed data and the specified key (step **1610**). As a final step, the distributed memory management client program **210** returns the result of access to the distributed data including the specified key to the job program **200** (step **1620**).

FIG. **12** is a flow chart of an inter-computer memory storage accessing process. When an access request is made to the computer **110** where the distributed data is disposed, the inter-computer memory storage accessing process in step **1330**, **1610** of FIG. **11** is performed by the distributed memory management client program **210** in the computer **110** that has received the access request.

When an access request is made by other computer **110**, the distributed memory management client program **210** checks if the received access request is one asking for a write access (step **1700**). If the received access request is not the write access, the distributed memory management client program **210** refers to the memory storage management information **212**, accesses an address in the memory storage **213** where the requested distributed data is held, and acquires the requested data (step **1710**). After acquiring the requested record, the distributed memory management client program **210** returns it to the computer **110** that has issued the access request (step **1715**).

If on the other hand step **1700** decides that the received access request is a write access request, the distributed memory management client program **210** refers to the memory storage management information **212** and updates the data held at the address in the memory storage **213** where the distributed data is held (step **1720**). The client program **210** further references the memory storage management information **212** based on the ID and key of the distributed data specified by the access request and then checks if the received access request is to the replicas of the distributed data (step **1800**).

If the received access request is not the one for the replica of the distributed data, the distributed memory management client program **210** queries the distributed memory management server program **220** of the management computer **120** to acquire the information about a computer **110** holding the replica of the distributed data including the specified key (step **1810**) and issues an access request for the replica of the distributed data including the specified key to the computer **110** identified by the acquired information (step **1815**). Upon receiving the result of the access request it has made for the replica of distributed data, the distributed memory management client program **210** returns the access result to the computer **110**, the source of the access request (step **1820**).

If step **1800** decides that the received access request is for the replica of the distributed data, the distributed memory management client program **210** skips step **1810** and **1815** and returns the result of access to the distributed data to the computer **110** that has made the access request.

FIG. **13** is a flow chart of a job execution acceptance process performed by the job execution management unit **221** in this embodiment.

The job execution management unit **221** acquires from the user hint information, according to which the data used during job execution will be distributively disposed in memories of a plurality of computers **110**. More specifically, the job execution management unit **221** needs only to acquire information necessary for setting individual items of the distributed data disposition hint information **226**, in the form of a file or an input through a user interface such as display and keyboard. The job execution management unit **221** holds the acquired hint information as the distributed data disposition hint information **226** in the memory **122** (step **1900**).

Next, the job execution management unit **221** hands the distributed data disposition hint information **226** to the distributed memory storage management unit **223** and requests it to distributively dispose the data **230** into the memories **112** of a plurality of computers **110** (step **1910**). After the distributive disposition of the data **230** into the memories **112** of computers **110** is complete, the job execution management unit **221** receives from the distributed memory storage management unit **223** information about the computers **110** in which the distributed data is disposed (step **1920**). Then the job execution management unit **221** creates job execution management information **222** based on the computer information received from the distributed memory storage management unit **223** and the information about the job to be executed, and holds it in the memory **122** (step **1930**).

FIG. **14** is a flow chart of a job execution process performed by the job execution management unit **221** in this embodiment.

The job execution management unit **221** refers to the execution status **450** in the job execution management information **222** to see if there is any job **200** that has failed to end normally due to a fault (step **2000**). If no abnormally ended job is found, the job execution management unit **221** references the execution status **450** to check if all the jobs are completed normally. When all the jobs are finished normally, the job execution management unit **221** ends the job execution process (step **2005**). If on the other hand not all jobs have yet been finished, the job execution management unit **221** references the job execution management information **222** to

see if any job **200** using distributed data is waiting to be executed. If the waiting job **200** using distributed data is not found, the job execution management unit **221** returns to step **2000** (step **2100**). If such a job is found at step **2100**, the job execution management unit **221** references the job execution management information **222** to check whether, among the computers **110** assigned to execute the waiting jobs, there are any computers **110** that are executing other jobs. If such a computer is found, the job execution management unit **221** returns to step **2000** (step **2110**).

If, among the computers **110** assigned to execute the waiting jobs, no computers are found that are currently executing other jobs, the job execution management unit **221** requests these computers **110** to execute the assigned jobs using distributed data (step **2120**).

If step **2000** finds any job **200** that has failed to end normally, the re-execution using replicas of distributed data needs to be done. The job execution management unit **221** references the re-execution information by using the re-execution ID **460** of the job execution management information **222** as a key and checks whether there is any job **200** waiting to be re-executed using replicas of distributed data (step **2010**). If such a waiting job **200** exists, the job execution management unit **221** further refers to the re-execution information to check whether the computer **110** that is assigned to execute the job **200** waiting to be re-executed is currently executing other job. If the computer **110** of interest is found to be executing other job, the job execution management unit **221** returns to step **2000** (step **2020**).

If the computer **110** assigned to execute the job **200** waiting to be re-executed is found not executing other job, the job execution management unit **221** requests that computer **110** to re-execute the job using replicas of distributed data. Then, the job execution management unit **221** returns to step **2000** (step **2030**).

If, as a result of referencing the re-execution information at step **2010**, no job **200** is found waiting to be re-executed that uses the replicas of distributed data, the re-execution using the replicas of distributed data has already been completed. Then, the job execution management unit **221** references the distributed data disposition hint information **226** to check for a designation of a joining process on the results of re-executions by the computers **110** using the replicated distributed data (step **2200**). Then the job execution management unit **221** requests the computer **110** that has re-executed the job using the replicas of distributed data to execute the joining process specified, before exiting the processing (step **2210**).

FIG. **15** is a flow chart of a job result acceptance process performed by the job execution management unit **221**.

Upon receiving a job result notification from the computer **110**, the job execution management unit **221** checks whether the notification received is a notification of the process for joining the results of re-execution using replicas of distributed data (step **2300**). If the result notification received is a notification of the process for joining the results of re-execution using the distributed data replicas, the job execution management unit **221** requests the distributed memory storage management unit **223** to update the disposition information about the rejoined data of re-execution results.

Next, the job execution management unit **221** references the job execution management information **222** and requests the distributed memory storage management unit **223** to release the distributed data that will not used in the subsequent jobs (step **2320**). Further, the job execution management unit **221** references the job execution management information **222** and updates the execution status of the original job **200** that has been re-executed (step **2330**).

If step **2300** decides that the received result notification is not about the process for joining the results of re-execution using the distributed data replicas, the job execution management unit **221** checks whether the job result notification received from the computer **110** is a notification of the result of re-execution of the job using the replicas of distributed data (step **2400**). If so, the job execution management unit **221** references the re-execution ID **460** of the job execution management information **222** and updates the execution status of the re-executed job (step **2410**).

If step **2400** decides that the result notification is not about the result of job re-execution using the distributed data replicas, the job execution management unit **221** updates the execution status **450** of the job execution management information **222** according to the result notification of job execution received from the computer **110**.

Next, the job execution management unit **221** checks whether the execution of job using the distributed data is normally completed (step **2510**). If it is decided that the job execution using distributed data has not finished normally, the job execution management unit **221** receives from the distributed memory storage management unit **223** information about the computer **110** holding the replicas of distributed data used in the execution of the job that has failed to be completed normally, and registers it with the re-execution information (step **2515**).

On the other hand, if step **2510** decides that the execution of a job using distributed data has normally been completed, the job execution management unit **221** refers to the job execution management information **222** to see if the execution of a job using other pieces of distributed data associated with the original data **230** is normally finished. If any jobs remain that failed to be normally completed, the job execution management unit **221** ends the processing (step **2520**).

If step **2520** decides that the execution of jobs using other pieces of distributed data has normally been completed, the job execution management unit **221** refers to the job execution management information **222** to check for distributed data that will not be used in subsequent jobs, and requests the distributed memory storage management unit **223** to release the distributed data.

FIG. **16** is a flow chart of distributed data disposition process performed by the distributed memory storage management unit **223** in this embodiment. This process is triggered by a distributed data disposition request from the job execution management unit **221**.

In the distributed data disposition process, the distributed memory storage management unit **223** acquires hint information **226**, based on which the data **230** used during job execution is distributively disposed in memories of a plurality of computers **110**, along with the distributed data disposition request, from the job execution management unit **221** (step **2600**). The distributed memory storage management unit **223** refers to the distributed data disposition information **225** to see if data already distributively disposed for the execution of the preceding jobs is included in the data requested to be distributively disposed (step **2605**).

If the data requested to be distributively disposed does not include the data already distributively disposed for the execution of the preceding jobs, the distributed memory storage management unit **223** references the distributed memory storage management information **224** to allocate as many computers as necessary for the requested distributive disposition of data, in order from the least memory use to the greatest (step **2610**). If on the other hand the data already distributively disposed for the execution of the preceding jobs is included in the data requested to be distributively disposed,

the distributed memory storage management unit **223** allocates the same computers **110** as those for the preceding jobs (step **2620**).

After securing the computers **110** at step **2610** or **1620**, the distributed memory storage management unit **223** references the distributed data disposition hint information **226**, requests the distributed memory management client program **210** to distributively dispose the distributed data making up the data requested to be distributively disposed and then registers information about these computers (computer IDs) with the distributed data disposition information **225** (step **2630**). Next, the distributed memory storage management unit **223** calculates the number of records of the distributed data disposed in the allocated computers **110** and registers it in the corresponding entry in the distributed data disposition information **225** (step **2635**).

With the above information registered with the distributed data disposition information **225**, the distributed memory storage management unit **223** checks whether the replica ID **770** is set in the distributed data disposition information **225** to determine whether the distributive disposition of the replicas for all the distributed data disposed in the allocated computers **110** is finished. If the distributive disposition of the replicas for all the distributed data is found completed, the distributed data disposition process is ended (step **2700**).

If on the other hand there is distributed data whose replica disposition has not yet been finished, the distributed memory storage management unit **223** references the distributed data disposition hint information **226** to determine whether the distributed data, from which a replica will be made, can be redistributed in a field that is used as a key (step **2710**). If it is decided that the distributed data can be redistributed, the distributed memory storage management unit **223** performs a redistribution disposition process described later (step **2720**). If not, the distributed memory storage management unit **223** performs a redisposition process described later (step **2730**).

FIG. **17** is a flow chart of a redistribution disposition process performed to redistribute the distributed data when creating a replica during the distributed data disposition process.

If it is found that the distributed data can be redistributed and disposed, the distributed memory storage management unit **223** references the distributed data disposition hint information **226** to see whether the replica generation policy is a leveling (step **2800**). If so, the distributed memory storage management unit **223** references the distributed data disposition information **225** and adjusts the range of value in that field which is used as a key during redistribution so that ratios of the numbers of records of distributed data distributively disposed in other computers **110** than those with the distributed data, from which replicas are to be made, will, after the redistribution, become reciprocals of the ratios (step **2810**). After adjusting the range of value in that field which is used as a key during redistribution, the distributed memory storage management unit **223** according to the range of field value requests the distributed memory management client program **210** in those computers **110** in which the replicas are to be disposed that the client program **210** dispose the replicated distributed data (step **2815**).

Then, the distributed memory storage management unit **223** registers the information about the distributed data replicas in the replica information and also registers its replica ID in a replica ID column in the distributed data disposition information **225** (step **2830**).

If on the other hand step **2800** decides that the replica generation policy is not a leveling, the distributed memory storage management unit **223** references the distributed data disposition hint information **226** and, according to the range of value in the field to be used as a user-specified key, requests the distributed memory management client program **210** executed in other computers **110** than those with the distributed data that the client program **210** dispose the replicated distributed data. After this, the distributed memory storage management unit **223** proceeds to step **2830** (step **2820**).

FIG. **18** is a flow chart of a redisposition process performed when the distributed data cannot be redistributed during the process of making a replica in the distributed data disposition process.

When the distributed data cannot be distributively disposed again, the distributed memory storage management unit **223** references the distributed data disposition hint information **226** to determine whether the replica making policy is a leveling. (step **2900**). If the replica making policy is a leveling, the distributed memory storage management unit **223** references the distributed data disposition information **225** and adjusts the number of records in which to dispose the distributed data, by using reciprocals of ratios of the number of records of distributed data held in other computers **110** than those with the distributed data, from which replicas are to be created, in order to level the volumes of distributed data disposed in the computers **110** (step **2910**). After the adjustment of the number of records, the distributed memory storage management unit **223** according to the adjusted number of records requests the distributed memory management client program **210** in the remaining computers **110** to dispose the distributed data replicas (step **2915**).

After this, the distributed memory storage management unit **223** registers the information about the distributed data replicas with the replica information and also registers their replica IDs in the replica ID column of the distributed data disposition information **225** (step **2930**).

If on the other hand step **2900** decides that the replica making policy is not a leveling, the distributed memory storage management unit **223** references the distributed data disposition information **225** and requests the distributed memory management client program **210** in one of the remaining computers **110**—other than those with distributed data from which replicas are to be created—which has the least number of records that the client program **210** dispose the distributed data replicas. Then, the distributed memory storage management unit **223** proceeds to step **2930** (step **2915**).

FIG. **19** is a flow chart of a distributed data disposition update process performed by the distributed memory storage management unit **223** in this embodiment. When a job is re-executed using the replicas of distributed data, this normally results in the data being disposed differently than when the original distributed data was processed. In such situations the distributed data disposition update process is performed to update the disposition information.

Upon receiving a request for updating the disposition information on the joined re-execution result data from the job execution management unit **221** (step **3000**), the distributed memory storage management unit **223** references the distributed data disposition information **225** and updates the information about the computers **110** with the original distributed data corresponding to the re-execution result data to the information about the computers **110** in which the re-execution result data is disposed (step **3010**).

FIG. **20** is a flow chart of a distributed data releasing process performed by the distributed memory storage management unit **223** in this embodiment. This process is triggered by a release request issued by the job execution management unit **221** at step **2530** during the job result receiving process.

The distributed memory storage management unit **223** acquires from the job execution management unit **221** a distributed data release request and a data ID as information about the distributed data to be released (step **3100**). The distributed memory storage management unit **223** references the replica information by using as a key the replica information ID **770** that was registered in connection with the data ID acquired as the distributed data disposition information **225** and locates the computers **110** in which the distributed data replicas to be released are disposed. The distributed memory storage management unit **223** then requests the distributed memory management client program **210** in the located computers **110** to release the areas of memory storage **213** in which the replicas are stored (step **3110**). The distributed memory storage management unit **223** further references the distributed data disposition information **225** to locate the computers **110** in which the distributed data of the acquired data ID is disposed and requests the distributed memory management client program **210** in these computers to release the areas of the memory storage **213** in which the distributed data of interest is stored (step **3120**).

After issuing a memory release request to the associated computers **110**, the distributed memory storage management unit **223** deletes the disposition information about the distributed data for which the release request has been made (step **3130**).

FIG. **21** is a flow chart of a distributed data disposition notification process performed by the distributed memory storage management unit **223** in this embodiment. This process is performed in response to a query from the distributed memory management client program **210**, i.e., in response to a query issued by step **1320**, **1600** in the memory storage access process and by step **1815** in the inter-computer accessing process. This query includes as information an ID of the distributed data of interest and a key to locate records.

Upon receiving the inquiry from the distributed memory management client program **210** in a computer **110** (step **3200**), the distributed memory storage management unit **223** based on the ID of the distributed data specified by the inquiry checks whether the received inquiry about the disposition of the distributed data concerns the replica of the distributed data (step **3205**).

If the received inquiry is for the replica of distributed data, the distributed memory storage management unit **223** references the replica ID **770** of the distributed data disposition information **225** and searches for a computer **110** in which the replica including the key specified by the inquiry is disposed (step **3210**). If on the other hand the received inquiry does not concern the disposition of replica, the distributed memory storage management unit **223** references the distributed data disposition information **225** and searches for a computer **110** in which the distributed data including the key specified by the inquiry is disposed (step **3220**).

If at step **3210** or **3120** the computer **110** of interest is found, the distributed memory storage management unit **223** returns the information including the computer ID to the distributed memory management client program **210** in the computer, the source of the inquiry (step **3230**).

In this embodiment, the distributed memory management server program distributively dispose distributed data and its replicas in a plurality of computers according to the distributed data disposition hint information entered by the user. The disposition of the replicas among the computers is determined according to the ratio of the number of distributed data records disposed in each computer. This allows the processing executed in each of the computers, including the re-execution of jobs in the event of a fault, to be leveled among the computers. Further, even with the distributed data that cannot be redistributed, the distributed memory management client program **210** can have their replicas so distributively disposed as to level the amount of memory use among the computers by making the accesses from jobs to the redistributed replicas look transparent to those accesses to the original distributed data.

This invention has been described in detail with reference to the embodiment. It is needless to say that the invention is not limited to the above embodiment and that various modifications and changes may be made without departing from the spirit of the invention.

This invention is applicable to the processing method performed in the event of a fault in a computer system and particularly the method of re-executing data processing in the event of a fault in a system where large volumes of data are parallelly processed by a plurality of computers.

It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

The invention claimed is:

1. A data processing method in a computer system having a plurality of first computers to distributively execute data processing, a second computer to manage the execution of the data processing by the plurality of the first computers, a storage device storing data used in the data processing, and a network interconnecting the plurality of the first computers, the second computer and the storage devices, the data processing method comprising the steps of:

according to hint information given to the second computer and indicating a policy on the distributive disposition of the data in the plurality of the first computers, dividing the data held in the storage device into a plurality of pieces of distributed data;

distributively disposing the distributed data and replicated data of each piece of the distributed data in memories of the plurality of the first computers; and

performing data processing by the plurality of the first computers using the distributed data disposed in each of the first computers,

wherein, in the event of a fault in any of the first computers, the data processing that was being executed in the faulty first computer at the time of the fault is re-executed by another first computer that holds the replicated data of the distributed data disposed in the faulty first computer,

wherein the hint information includes information about whether the distributed data can be further distributively disposed, and

wherein, when the hint information indicates that the distributed data can be further distributed, the distributively disposing step further includes dividing each of the pieces of the distributed data according to the hint information, creating the replicated data of the further divided distributed data, and disposing the pieces of the replicated data in first computers other than the first computer in which is disposed the original distributed data from which the replicated data has been created.

2. A data processing method according to claim **1**,

wherein, when the hint information indicates that the distributed data cannot be further distributed, the distributively disposing step distributively disposes the replicated data of each piece of the distributed data so that the

volumes of the distributed data and the replicated data placed in the first computers are leveled among the computers.

3. A data processing method according to claim **2**,

wherein the hint information includes information specifying a processing method performed on the result of re-execution of data processing using the replicated data, and

wherein, after the re-execution of data processing using the replicated data, the second computer requests, according to the information specifying the processing method, the first computers to perform processing on the result of re-execution of data processing using the replicated data.

4. A data processing method according to claim **1**,

wherein, when the hint information indicates that the distributed data cannot be further distributed, the distributively disposing step disposes the replicated data in a first computer with a least amount of the disposed distributed data.

5. A computer system comprising:

a storage device storing data;

a plurality of first computers connected with the storage device and configured to manage data processing using the data; and

a plurality of second computers connected with the first computers and configured to distributively execute the data processing,

wherein the first computers each have a distributive disposition unit and an execution management unit,

the distributive disposition unit configured to reference given hint information indicating a policy of distributive disposition of the data in a plurality of the second computers, divide the data held in the storage device into a plurality of pieces of distributed data and distributively dispose the pieces of the distributed data and each piece of replicated data of the distributed data into memories of the plurality of the second computers, and

the execution management unit configured to request the second computers to execute the data processing and, in the event of a fault in any of the second computers, request another second computer to re-execute the data processing that was being executed in the faulted second computer at the time of fault,

wherein the second computers each have a memory management unit and a data processing unit,

the memory management unit being configured to hold the distributed data in a memory of its own computer in response to a request from the distributive disposition unit, and

the data processing unit being configured to execute the data processing in response to a request from the execution management unit,

wherein the hint information includes information indicating whether each piece of replicated data of the distributed data can be further distributively disposed.

6. A computer system according to claim **5**, wherein, when the hint information indicates that the distributed data can further be distributed, the distributive disposition unit according to the hint information further divides each piece of the distributed data, creates the duplicated data and disposes each piece of the duplicated data in second computers other than the second computer in which is disposed the original distributed data from which the replicated data has been created.

7. A computer system according to claim **6**, wherein, when the hint information indicates that the distributed data cannot be further distributed, the distributive disposition unit disposes the duplicated data of each piece of the distributed data so that the volumes of the distributed data and the duplicated data disposed in the second computers are leveled among the computers.

8. A computer system according to claim **6**, wherein, when the hint information indicates that the distributed data cannot be further distributed, the distributive disposition unit disposes the duplicated data in a second computer with a least amount of the disposed distributed data.

9. A computer system according to claim **5**, wherein the hint information includes information specifying a processing method performed on the result of re-execution of data processing using the replicated data.

10. A computer system according to claim **9**, wherein, after the re-execution of data processing using the replicated data, the distributive disposition unit requests, according to the information specifying the processing method, the second computers to perform processing on the result of re-execution of data processing using the replicated data.

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